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Miscellaneous Paper 116

Summary of Field Work, 1983, by the Ontario Geological Survey

edited by

John Wood, Owen L. White,
R.B. Barlow, and A.C. Colvine

1983

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Natural
Resources

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Minister

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Deputy Minister

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Foreword

During 1983, the Ontario Geological Survey carried out a large number of independent geological, geophysical, geochemical, geochronological, and mineral deposit studies. In addition, studies were undertaken in cooperation with the ministry's regional geological staff, personnel from a number of universities, and several private consulting firms. Project involvement is summarized in the section introductions and individual summaries.

Funding for a number of regional stimulation projects was provided by the Ontario Ministry of Northern Affairs, the Government of Canada, and the Ontario Ministry of Natural Resources, and for Hydrocarbon Energy Resources Program (HERP) by the Ontario Ministry of Treasury and Economics under the Board of Industrial Leadership and Development (BILD) Program. Funding acknowledgments are given in the individual summaries.

The locations of the areas investigated are shown on 2 maps of the Province at the beginning of this report. The preliminary results of the work are outlined in this summary, which contains reports prepared by leaders of each of the projects. In these reports, some emphasis has been placed on the economic aspects of the different investigations. It is the hope of the Ontario Geological Survey that the information thus provided will help in the mineral resource evaluation of these areas, and so will be a valuable aid to mineral prospecting and resource planning in the Province. Also, as a direct result of this summer's work, research was undertaken on a number of theses at the undergraduate and graduate levels.

Coloured maps and final detailed reports covering most of the field projects are being prepared for publication. In the interim, uncoloured preliminary geoscience maps with comprehensive marginal notes will be released for distribution, mainly during the winter of 1983-1984. Notices of the releases will be mailed to all persons or organizations on the Mineral Resources group notification list, and will be published in the technical journals and other media.

E.G. Pye
Director
Ontario Geological Survey

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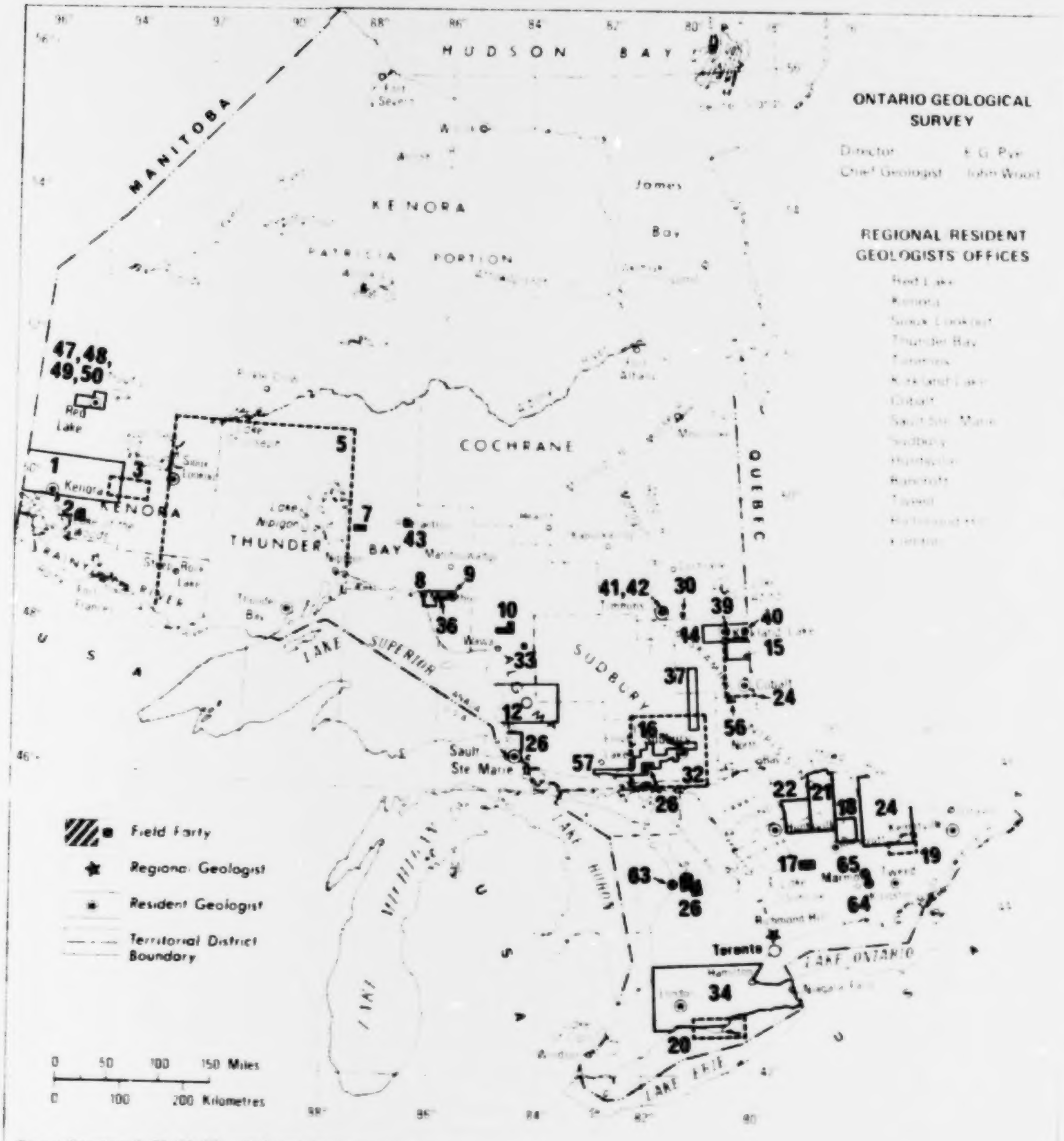

HUDSON BAY
MANITOBA
KENORA
PATRICIA PORTION
James Bay
COCHRANE
QUEBEC
KENORA
THUNDER BAY
RAINY RIVER
SUDBURY
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ONTARIO
LAKE ERIE
U S A
Red Lake
Kenora
Sioux Lookout
Lake Nipigon
Thunder Bay
Timmins
Kirkland Lake
Cobalt
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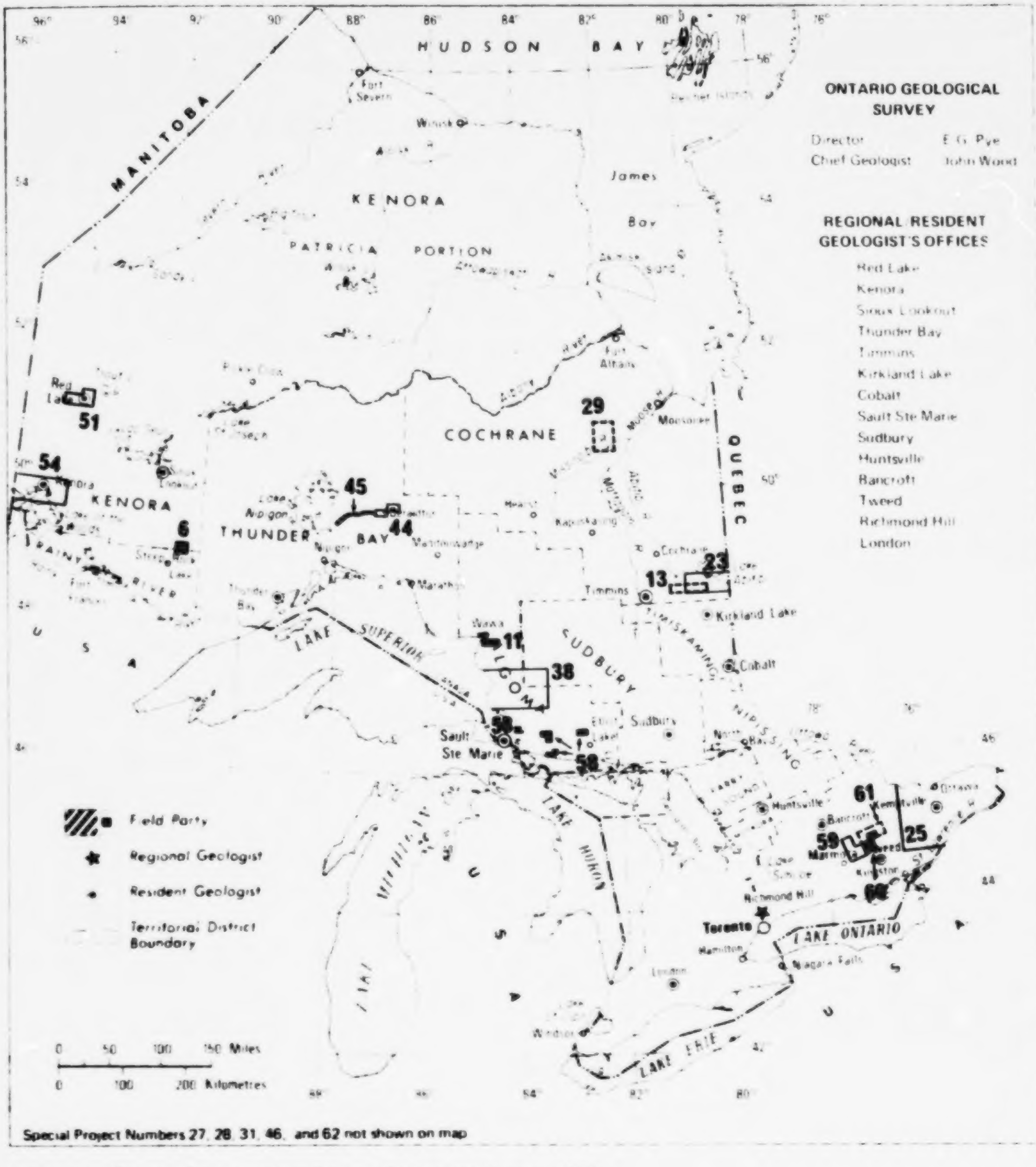
ONTARIO GEOLOGICAL SURVEY
Director E.G. Pye
Chief Geologist John Wood
REGIONAL RESIDENT GEOLOGISTS' OFFICES
Red Lake
Kenora
Sioux Lookout
Thunder Bay
Timmins
Kirkland Lake
Cobalt
Sault Ste. Marie
Sudbury
Huntsville
Bancroft
Tweed
Richmond Hill
London
Field Party
Regional Geologist
Resident Geologist
Territorial District Boundary
0 50 100 150 Miles
0 100 200 Kilometres

Project Numbers 4, 35, 52, 53, and 55 not shown on map.

Location of Field Parties of the Ontario Geological Survey, 1983


HUDSON BAY
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ONTARIO GEOLOGICAL SURVEY
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REGIONAL RESIDENT GEOLOGIST'S OFFICES
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Huntsville
Bancroft
Tweed
Richmond Hill
London
KENORA
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James Bay
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THUNDER BAY
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NIPISSING
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LAKE HURON
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LAKE ONTARIO
LAKE ERIE
Fort Severn
Winisk
Moosonee
Fort Albany
Red Lake
Kenora
Sioux Lookout
Thunder Bay
Nipigon
Geraldton
Marathon
Hearst
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Cochrane
Timmins
Kirkland Lake
Cobalt
Wawa
Sault Ste Marie
Sudbury
North Bay
Huntsville
Bancroft
Tweed
Kingston
Ottawa
Toronto
Richmond Hill
Hamilton
Niagara Falls
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Field Party
Regional Geologist
Resident Geologist
Territorial District Boundary
0 50 100 150 Miles
0 100 200 Kilometres
Special Project Numbers 27, 28, 31, 46, and 62 not shown on map

Location of Special Projects of the Ontario Geological Survey, 1983.

Conversion Factors for Measurements in Ontario Geological Survey Publications

If the reader wishes to convert imperial units to SI (metric) units or SI units to imperial units the following multipliers should be used:

CONVERSION FROM SI TO IMPERIAL			CONVERSION FROM IMPERIAL TO SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
			LENGTH		
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709 7	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
			AREA		
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
			VOLUME		
1 cm^3	0.061 02	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.308 0	cubic yards	1 cubic yard	0.764 555	m^3
			CAPACITY		
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
			MASS		
1 g	0.035 273 96	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 75	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 62	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 908 8**	t
			CONCENTRATION		
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

1 ounce (troy)/ton (short)	20.0	pennyweights/ton (short)
1 pennyweight/ton (short)	0.05	ounce (troy)/ton (short)

NOTE—Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries published by The Mining Association of Canada in cooperation with the Coal Association of Canada.

Precambrian Geology Programs

Summary of Activities, Precambrian Geology Section, 1983

John Wood[1]

The primary goals of the field program of the Precambrian Section are to increase the wealth of the Province through the encouragement and guidance of mineral resource exploration and development, and to provide a geological database that can be utilized for land use co-ordination and similar purposes.

In 1983, 18 projects were carried out, 16 by Section Staff, 1 by Ontario Ministry of Natural Resources Regional Staff, and 1 by university personnel. There were 9 detailed mapping projects, 4 synoptic mapping projects, 1 compilation mapping project, and 4 projects oriented towards specific problems. Of the 9 detailed mapping projects, 4 projects were funded externally: 2 by the Federal Government and the Ontario Government, under the Northern Ontario Rural Development Agreement (NORDA); 1 by the Ontario Ministry of Northern Affairs, through the Northern Ontario Geological Survey (NOGS); and 1 jointly by the Ontario Ministry of Northern Affairs and the Ontario Ministry of Natural Resources, as part of Operation Black River-Matheson (BRiM). The source of funding, if other than from our base budget, is shown on the individual summaries.

The diversification away from detailed mapping is in response to an environment of constraint, under which any program has to utilize its resources for maximum effectiveness at minimum cost. For the same reasons, projects were directed towards readily accessible, high to moderate mineral potential areas.

Detailed Mapping

Detailed mapping of Precambrian bedrock has traditionally been the primary role of the Precambrian Section. The product of this mapping is the fundamental building block of a Precambrian geology database.

In the Long Bay area, Glen Johns completed a 3-year mapping program in the eastern Lake of the Woods region. The area has potential for gold in silicified-carbonatized shear zones within mafic metavolcanics, a situation akin to the Nuinsco Resources Limited deposit at Cameron Lake. It also has base-metal potential in a geological situation comparable to the Maybrun Mine.

Mike Jackson mapped the western half of the Lumby Lake area, thereby completing a 2-year program. Extensive carbonatization and some silicification of volcanic and mafic intrusive rocks indicates an environment favourable for gold mineralization. There is potential also for base metals in metavolcanics and combined base-metal-gold mineralization in sedimentary units. Molybdenum mineralization was noted in 2 locations.

In the Beardmore area, Maurice Carter mapped McComber and Vincent Townships. Gold mineralization occurs in 3 geological situations, and because of its apparent lithological/-stratigraphic and structural control, may be areally entensive.

In the White Lake area, just to the east of Hemlo, Giorgio Siragusa began a program to map the remainder of the "Hemlo belt". There appears to be potential for gold mineralization in the White Lake area; some of the gold values are associated with molybdenite mineralization.

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[1] Chief Geologist, Precambrian Geology Section, Ontario, Geological Survey, Toronto.

In the Wawa area, Nick Massey completed mapping of the Mishewawa Lake area. This area has several past-producing mines and is currently being actively explored for gold mineralization.

Also in the Wawa area, Ron Sage continued his multi-year detailed mapping program. The area covered has potential for base-metal and gold mineralization in a number of localities and geological situations. The southeastern part of Leclaire Township is underlain by coarse volcanic breccias and is pervasively silicified.

In the Black River-Matheson area, Norm Trowell and Rob Johnstone continued detailed mapping of the area adjacent to the Destor-Porcupine Fault. The area contains gold, base-metal, and asbestos mineralization, and includes 6 past-producing mines. Several directions and ideas for further exploration are suggested.

In the Sudbury area, Joanna Martins mapped Blezard Township which has a long history of exploration and production. The area has a large variety of rock formations; potential exists for copper-lead-zinc mineralization as well as nickel-copper-precious-metal mineralization.

In the Howland area, near Minden, Mike Easton started a multi-year mapping program in the Central Metasedimentary Belt of the Grenville Province. An area of complex geology, it has potential for industrial minerals, particularly marble, and for uranium, thorium, molybdenite, and gold.

Synoptic Mapping

Synoptic Mapping is carried out in an area that already has a geological database. Often the database is incomplete or has been produced by different workers. The synoptic mapping is intended to extrapolate across information gaps, integrate the existing geological information, and focus on the solution of specific aspects of the geology that will aid in assessing the mineral potential of an area.

In the Batchawana area, Eric Grunsky completed field work for the Batchawana Synoptic project. One of the aims of this project is to develop an integrated computer database of field, economic geology, laboratory, and thin section data, for storage, retrieval, and archival purposes. This summer's investigations have revealed a number of areas with base metal and gold potential. Neil Township, a formerly very inaccessible area, appears particularly worthy of consideration.

In the Kirkland Lake-Larder Lake-Englehart area, Larry Jensen continued his stratigraphic and structural analysis of the Abitibi "greenstone belt". A number of localities and stratigraphic units are suggested as targets for systematic gold and base-metal mineralization.

In the Northern Bancroft-Southern Barry's Bay area, Bob Thivierge undertook a regional synopsis of the structure, metamorphism, and basement-cover relationships of the Grenville Supergroup along its northern margin. The area has potential, primarily for industrial minerals, particularly graphite, but also corundum and nepheline. Potential for copper-nickel mineralization is also outlined.

In the Ardoch-Dalhousie Lake-Lavant area, Liba Pauk undertook a short field study to better unravel the lithostratigraphy and structure of a particularly complex area, underlain in part by Flinton Group rocks.

Compilation Mapping

Compilation Mapping is carried out within the context of compilation map revision. Several changes are anticipated for upcoming compilation maps. These include: a change in scale to 1:250 000; a switch to National Topographic Series (NTS) map sheets; more stratigraphic and geochronological detail; and, in conjunction with the Mineral Deposits Section, a more comprehensive treatment of mineral occurrences.

In the Lakehead-Atikokan area, Phil Thurston began the field work for that map sheet. Several stratigraphic units are outlined and environments of volcanism are suggested for these units.

Special Projects

Special Projects might best be termed within the content of this book "specific projects". They are geared towards the resolution of a specific problem. Often the field component of such projects is significantly less than 1 field-season long.

In the Kenora-Cedar Lake area, Gary Beakhouse, Greg Stott, and Richard Sutcliffe examined the southern part of the English River Subprovince with a view to better recognizing supracrustal lithologies and better understanding their stratigraphy and economic potential. The results are most interesting from a variety of viewpoints, including the problem of the missing felsic metavolcanics, nappe structures, and economic potential.

In the Dryden area, Fred Breaks concluded field work on lithophile mineralization in the Dryden Pegmatite Field. He gives a definitive appraisal of the mineralization, its genesis, how to prospect for it, and where more of such mineralization may be found.

The Sturgeon Lake "Gold Area" has been much in the news over the last year. During the mapping of the Sturgeon Lake area in the early 1970s, this area had very poor access. This summer Phil Thurston spent some time there with a view to placing the geology of the gold occurrences into a regional geological context. In his summary he outlines the location of a previously unrecognized fold structure, documents the form of gold mineralization, and suggests other localities where similar gold mineralization may occur.

The Hemlo-Heron Bay area was visited briefly by Tom Muir during the field season; the brevity of his field season was dictated by circumstances beyond the Precambrian Section's control. The purpose of his involvement in the area is outlined in his summary.

The summaries contained in this volume represent a first appraisal of raw geological field data, as do the preliminary maps which are in preparation for publication during the 1983-1984 Winter period. These summaries and maps were designed as a means to rapidly disseminate "highlights" and to present general outlines of new information. Extended analysis of field data, in conjunction with detailed office and laboratory research, for final report and map publication, can be expected to result in changes to the field terminology, interpretations, and concepts expressed in this summary.

No. 1 Geological Studies in the Kenora-Cedar Lake Area

G.P. Beakhouse[1], G.M. Stott[1], and R.H. Sutcliffe[1]

Introduction

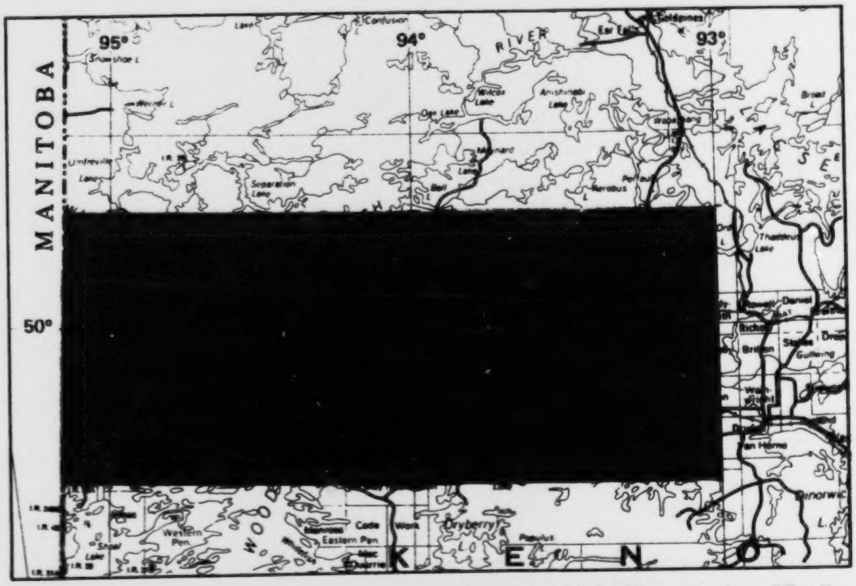
This project is an investigation of the southern part of the English River Subprovince with emphasis on the recognition, stratigraphy, and economic potential of supracrustal lithologies within this terrain. During the field season an irregularly shaped area, bounded by Latitudes 49°40′N and 50°15′N, and Longitudes 93°00′W and 95°10′W, was investigated. The Towns of Kenora and Vermilion Bay are respectively situated in the south-central and southeastern portions of the map area. Numerous provincial highways, secondary roads, and logging roads provide access to most of the area.

The area was previously mapped by Breaks, Bond, McWilliams, Gower, and Findlay (1975a, 1975b); Breaks, Bond, McWilliams, Gower, and Stone (1975); Breaks, Bond, Westerman, and Desnoyers (1976); Breaks, Bond, Westerman, and Harris (1976); and Breaks *et al.* (1978). The current survey focuses principally on units 4 (felsic to intermediate gneissic rocks) and 6 (metamorphosed felsic to intermediate plutonic rocks) of Breaks *et al.* (1978), together with their supracrustal inclusions.

A Statement of the Problem

The area studied lies within the Winnipeg River belt, the southern half of the English River Subprovince (Beakhouse, 1977; Breaks *et al.* 1978). The preponderance of massive to gneissic, felsic plutonic rocks in the Kenora-Cedar Lake area has lead to the perception that the area has little potential for the discovery of economic mineral deposits. As a result, the area has, until recently, received scant attention from mineral explorationists.

The earlier mapping (Breaks, Bond, McWilliams, Gower, and Findlay 1975a, 1975b; Breaks, Bond, McWilliams, Gower, and Stone 1975; Breaks, Bond, Westerman, and Desnoyers 1976; Breaks, Bond, Westerman, and Harris,



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

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1976) indicated a minor, but readily recognizable, supracrustal component within a plutonic complex. This supracrustal component includes amphibolitic mafic metavolcanics, pelitic metasediments, and banded chert-magnetite ironstone. Breaks *et al.* (1978) estimated that supracrustal rocks underlie approximately 1.6% of the area of the Winnipeg River Belt. Exploration carried out within the last decade by Noranda Exploration Company Limited and Selco Incorporated has indicated the existence of numerous conductors in the Cedar Lake area. Subsequent diamond drilling has confirmed that most of the anomalies correspond to narrow zones of sulphide mineralization, predominantly pyrite and pyrrhotite with minor chalcopyrite (Resident Geologist's Files, Ontario Ministry of Natural Resources, Kenora).

The association of sulphide mineralization with a highly metamorphosed, fragmentary "greenstone" sequence suggests an analogy with lower metamorphic grade "greenstone belts" that have historically been considered more attractive exploration targets. With this in mind the objectives of the present survey were:

1. to further define the characteristics and inter-relationships of the major lithologic groups outlined by Breaks *et al.* (1978)
2. to determine the proportion of the gneissic complex that could be of supracrustal origin and evaluate the potential for economic mineral deposits
3. to develop and evaluate criteria used to identify supracrustal rocks in high grade terrains

General Geology

The general geology of the area has been discussed previously by Breaks *et al.* (1978), thus only a brief summary and highlights of the results of the present survey will be discussed here. Homogeneous to gneissic meta-igneous rocks are concentrated along the southern margin of the Winnipeg River belt (Figure 1). To the north these rocks are intruded by immense batholithic complexes that generally have a more potassic composition and lack tectonic fabric. To the south, these rocks are in contact with the metavolcanics of the Wabigoon Subprovince. The nature of this contact is controversial, but it may be an unconformity which has subsequently been modified by faulting and younger intrusions (Clark *et al.* 1981; Beakhouse 1983). Supracrustal remnants are concentrated in the strongly heterolithic and gneissic zones.

The authors concur with the conclusion of Breaks *et al.* (1978) that the gneissic complex in this area is largely of plutonic origin with subordinate supracrustal remnants. The supracrustal remnants (predominantly amphibolitic mafic metavolcanics) are not randomly distributed inclusions but are concentrated, along with their anatectic derivatives, in narrow concordant zones within the gneissic stratigraphy. Intervening relatively homogeneous granodiorite and tonalite are interpreted to have been emplaced as sheet intrusions into the supracrustal stratigraphy. The supracrustal remnant zones tend to be extremely heterolithic due to:

1. early, small scale diking/sheeting of tonalitic intrusive rocks, which resulted in ductility contrasts that favoured the emplacement of subsequent intrusive phases into these zones
2. the presence of a variety of rock types which, when partially melted, produce distinctive melanosome-leucosome assemblages
3. the availability of a variety of rock types for mechanical mixing during deformation and/or partial melting
4. metamorphic segregation

The geometry of the gneissic stratigraphy is dominated by the development of structural domes (Figure 1). Structural basins are not as abundant and tend to be much smaller than the domes. Most of the domes (Dalles, Cedar, Twilight, Mystery, Herb; Figure 1) are relatively open, circular to elliptical in structure, with concentric, generally outward-dipping foliation patterns and down-dip mineral lineations. An exception to this generalization is the Monkeywrench structure (Figure 1) which is relatively tight with both eastern and western flanks dipping to the east (Figure 2) and northern and southern flanks dipping steeply away from the core. The continuity of a narrow amphibolite unit on its western flank around the Herb Lake dome indicates that the Monkeywrench structure is recumbent and overlies the Herb Lake dome (Figure 2). The small structural basins immediately west of the Herb Lake dome may represent the nose of the recumbent Monkeywrench structure. The dimensions and geometry of these features suggests that nappe tectonics may have occurred prior to doming by the Herb Lake pluton. Large scale tectonic interleaving has also been postulated in the Mystery and Twilight domes to explain the occurrence of paragneiss in the cores of domes (Westerman 1977).

Most of the western Winnipeg River belt is characterized by amphibolite facies metamorphic assemblages, but rocks of granulite facies rank occur in the Cedar Lake area (Thurston and Breaks 1978). The present survey outlined 3 zones based on mineral assemblages in mafic metavolcanic remnants. The zones are delineated based on the widespread occurrence of amphibole + plagioclase + quartz, clinopyroxene + amphibole + plagioclase ± quartz, and orthopyroxene + clinopyroxene + plagioclase ± amphibole ± quartz assemblages. There is no evidence that the orthopyroxene-free assemblages away from the Cedar Lake area are retrograded granulites. There is considerable overlap of these assemblages, probably reflecting compositional control. For example, clinopyroxene occurs locally in the amphibole + plagioclase ± quartz zone. Garnet occurs sporadically and retrograde biotite, chlorite, and epidote are common.

At present, the reason for this zonation of metamorphic mineral assemblages cannot be unambiguously explained. It is possible that regional compositional variations of mafic metavolcanics play a role in controlling the distribution of metamorphic mineral assemblages. A

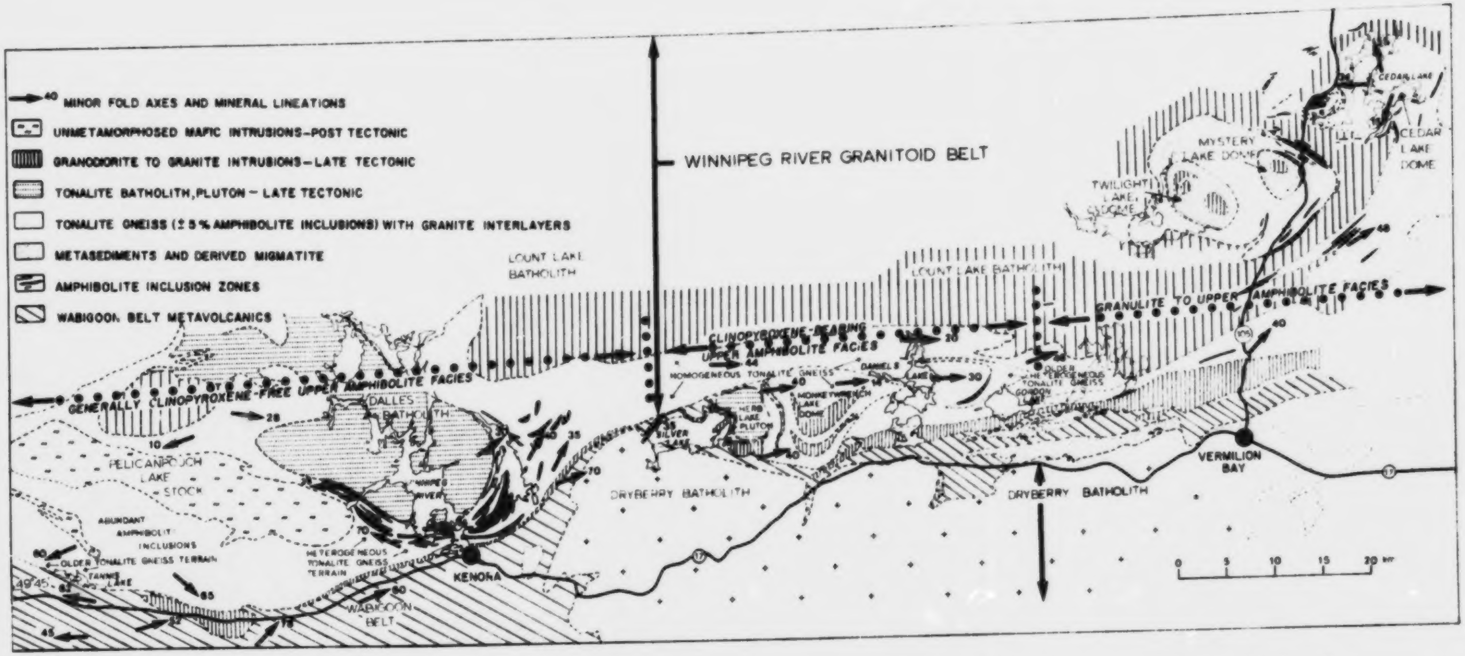
MINOR FOLD AXES AND MINERAL LINEATIONS
UNMETAMORPHOSED MAFIC INTRUSIONS–POST TECTONIC
GRANODIORITE TO GRANITE INTRUSIONS–LATE TECTONIC
TONALITE BATHOLITH, PLUTON – LATE TECTONIC
TONALITE GNEISS (± 5% AMPHIBOLITE INCLUSIONS) WITH GRANITE INTERLAYERS
METASEDIMENTS AND DERIVED MIGMATITE
AMPHIBOLITE INCLUSION ZONES
WABIGOON BELT METAVOLCANICS
WINNIPEG RIVER GRANITOID BELT
LOUNT LAKE BATHOLITH
LOUNT LAKE BATHOLITH
GENERALLY CLINOPYROXENE-FREE UPPER AMPHIBOLITE FACIES
CLINOPYROXENE-BEARING UPPER AMPHIBOLITE FACIES
GRANULITE TO UPPER AMPHIBOLITE FACIES
DALLES BATHOLITH
PELICANPOUCH LAKE STOCK
ABUNDANT AMPHIBOLITE INCLUSIONS
OLDER TONALITE GNEISS TERRAIN
HETEROGENEOUS TONALITE GNEISS TERRAIN
HOMOGENEOUS TONALITE GNEISS
SILVER LAKE
HERB LAKE PLUTON
DANIELS LAKE
OLDER HETEROGENEOUS TONALITE GNEISS
GORDON LAKE
TWILIGHT LAKE DOME
MYSTERY LAKE DOME
CEDAR LAKE
CEDAR LAKE DOME
DRYBERRY BATHOLITH
DRYBERRY BATHOLITH
KENORA
VERMILION BAY
WABIGOON BELT
17
17
105
49°45'
0
5
10
15
20 km

Figure 1. Geologic map of the southern part of the Winnipeg River granitoid belt between the Manitoba-Ontario border and the Red Lake road.

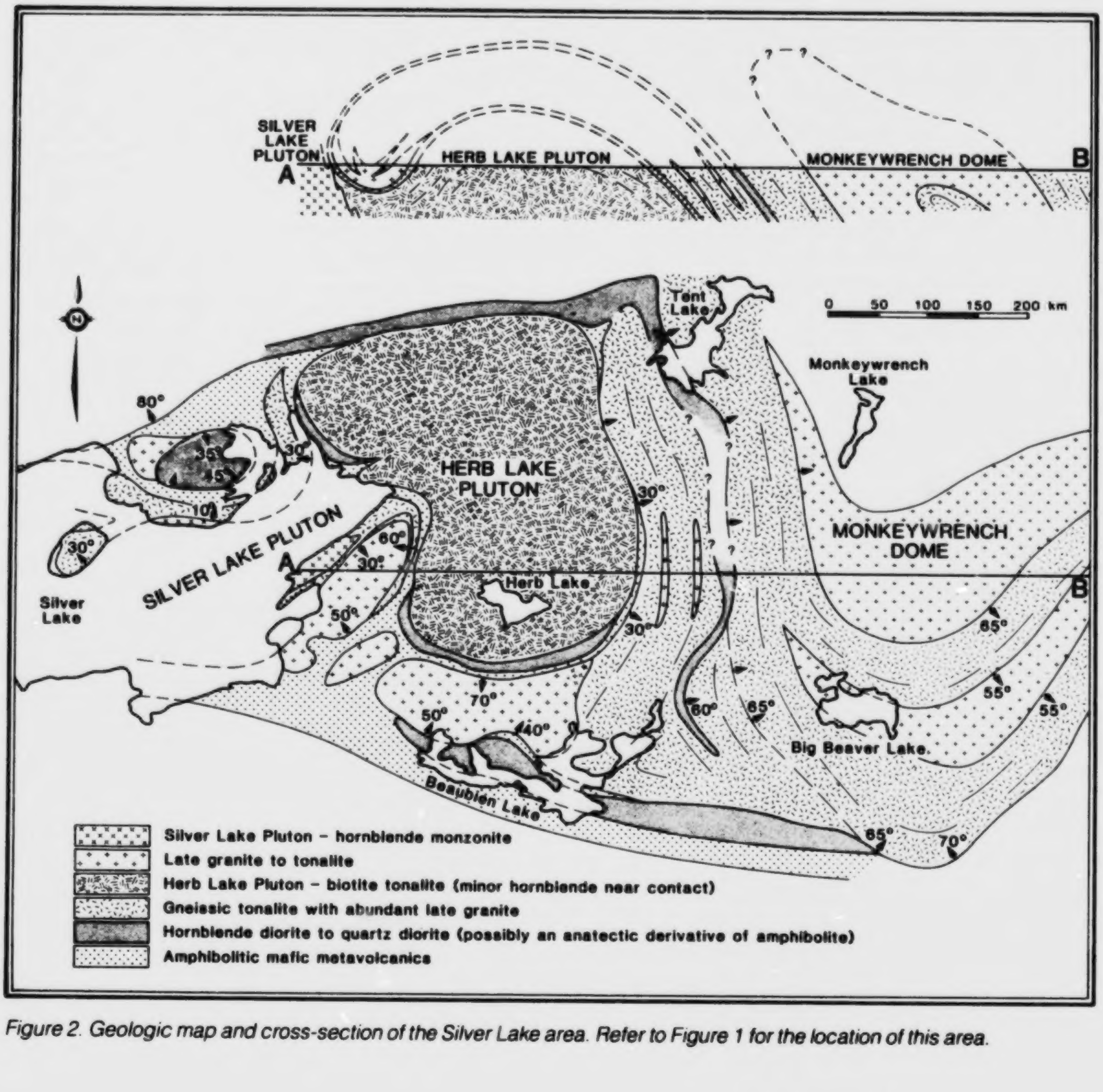
SILVER LAKE PLUTON
A
HERB LAKE PLUTON
MONKEYWRENCH DOME
B
Tent Lake
0 50 100 150 200 km
Monkeywrench Lake
80°
35°
45°
30°
10°
HERB LAKE PLUTON
30°
MONKEYWRENCH DOME
SILVER LAKE PLUTON
60°
30°
A
B
Silver Lake
Herb Lake
50°
30°
65°
70°
50°
40°
60°
65°
55°
55°
Big Beaver Lake
Beaubien Lake
65°
70°
Silver Lake Pluton - hornblende monzonite
Late granite to tonalite
Herb Lake Pluton - biotite tonalite (minor hornblende near contact)
Gneissic tonalite with abundant late granite
Hornblende diorite to quartz diorite (possibly an anatectic derivative of amphibolite)
Amphibolitic mafic metavolcanics

Figure 2. Geologic map and cross-section of the Silver Lake area. Refer to Figure 1 for the location of this area.

more plausible explanation is that these observations reflect a regional variation in metamorphic grade related to the exposure of progressively deeper crustal levels towards the Cedar Lake area.

Supracrustal Rocks in the Winnipeg River Belt

Mafic Metavolcanics

The most abundant and widespread supracrustal rocks in the Winnipeg River belt are of mafic metavolcanic origin. Their state of preservation is varied and includes non-migmatitic amphibolite to mafic granulite, agmatitic and veinitic migmatite with externally derived leucocratic phases, and anatectic migmatite consisting of variable proportions of paleosome, leucosome, and melanosome.

The mafic metavolcanic origin of these rocks is most apparent in the non-migmatitic mafic rocks. Highly deformed pillow structures can be identified in a few outcrops. Compared to the interior of pillows, the selvage edges are darker in colour and more mafic and rarely contain garnet and calc-silicate pods. More abundant are amphibolites with thin banding defined by textural and compositional alternations similar to those observed between pillow core and selvage. These rocks are interpreted to be highly deformed pillowed flows or pillow breccia. The calc-silicate clots that are common in pillowed flows are interpreted to result from seawater interaction with basalt, and their presence in otherwise massive amphibolites is thought to be evidence for a volcanic origin. Many amphibolites are massive and devoid of diagnostic criteria that can conclusively identify their origin. The spatial association of many of these rocks with zones in which pillowed mafic metavolcanics and banded ironstone are abundant suggests that they represent massive mafic flows and/or subvolcanic sills. A small proportion of the amphibolites may represent disrupted dikes.

The mafic metavolcanics are commonly migmatitic due to either intrusion of an externally derived felsic plutonic phase or *in situ*partial melting. Distinction between these 2 processes is made on the basis of the composition of the more leucocratic phase (anatectic melts are tonalitic to dioritic, whereas unrelated intrusive phases may have any composition), and, more importantly, on the presence and abundance of a corresponding melanosome phase. It is important that the anatectic component be considered when determining proportions of different supracrustal rock types. Primary structures such as pillows and derived banding may be identifiable in the paleosome component at low to moderate degrees of melting. Calc-silicate pods appear to be highly refractory and have been observed even at advanced stages of anatexis.

Felsic Metavolcanics

No rocks of felsic metavolcanic origin have been unequivocally identified in the Winnipeg River belt. Most of the felsic igneous and meta-igneous rocks were clearly intruded into their present levels. Some fine-grained tonalites that are volumetrically minor and among the area's oldest felsic meta-igneous phases, were possibly derived from felsic metavolcanics, but no clear evidence for such an origin was noted during this survey.

The apparent paucity of felsic metavolcanic remnants in this and other plutonic complexes is perplexing in view of the widespread occurrence of other types of supracrustal rocks. Possibly felsic metavolcanics are present in these fragmentary "greenstone belts" but we cannot recognize them as readily as the mafic variety. Alternatively, the supracrustal sequences in the granitoid complexes may be fundamentally different from those in the better preserved "greenstone belts". Future studies are planned to address these problems.

Metasediments

In the area examined by the present survey, clastic metasediments were only recognized in the core of the Mystery and Twilight domes. These migmatitic rocks are readily recognizable as metasediments because of their distinctive pelitic compositions and the preservation, even at advanced stages of anatexis, of original sedimentary bedding.

Chemical metasediments (chert and banded chert-magnetite ironstone) are rare, and occur principally in association with mafic metavolcanics in the northeastern portion of the area investigated. Such rocks are readily identifiable in high grade terrains by their distinctive compositions. Original sedimentary bedding is generally well preserved and further aids identification.

Extent and Distribution of Supracrustal Rocks

This work has demonstrated that remnants of a supracrustal sequence are heterogeneously distributed throughout this part of the Winnipeg River belt. Remnants are relatively abundant (15 to 30%) in the areas between Silver Lake and the Manitoba border, and in the vicinity of Cedar and Clay Lakes, but they are less abundant in the central part of the area between Silver Lake and the Red Lake road. Although these units are frequently present as randomly oriented fragments in plutonic rocks on an outcrop scale, on a larger scale, distinct, laterally continuous supracrustal stratigraphy can be recognized within and parallel to the gneissic stratigraphy.

Potential for Economic Mineral Deposits

In view of the abundance of supracrustal rocks and presence of narrow zones of barren to low grade sulphide mineralization in this area, it is apparent that the low economic potential long attributed to this and other granitoid terrains may need re-evaluation. The absence of recognizable felsic metavolcanics suggests, by analogy with better preserved "greenstone belts", that the Winnipeg River belt may not be a favourable area for large, stratabound Cu-Zn deposits. Other types of deposits associated with basalt and ironstone (e.g. Maybrun-type Cu-Au in basalt) may be present. Other granitoid complexes should be investigated to identify the extent and nature of fragmentary "greenstone belts" and the type of mineralization they may contain.

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No. 2 Long Bay Area, District of Kenora

G.W. Johns[1]

Introduction

A mapping project in the eastern Lake of the Woods region begun in 1981 (Johns 1981, 1982; Johns and Richey 1982; Johns and Davison 1983a, 1983b) was completed during the summer of 1983, with 150 km² mapped at a scale of 1:15 840. The area covered is bounded by Latitudes 49°22'30"N and 49°30'53"N, and Longitude 93°45'00"W to the western boundary as shown on the location map. The Village of Sioux Narrows is 19 km west-southwest of the centre of the area and Kenora is 64 km to the northwest.

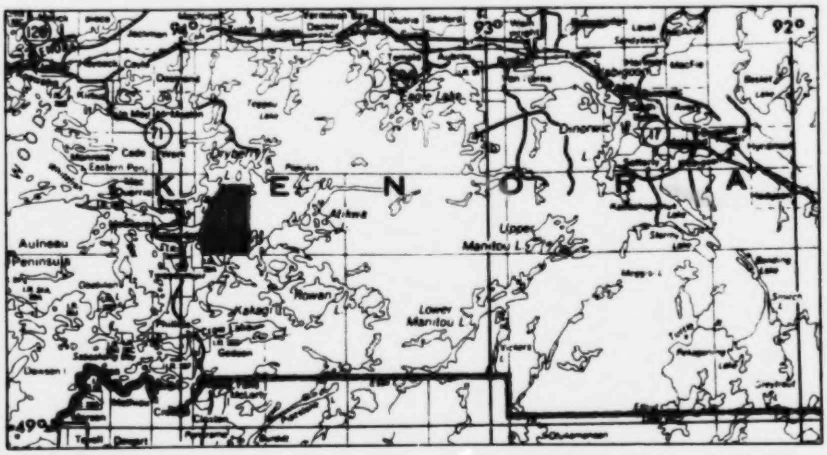
Access to the central portion of the area is via a Ministry of Natural Resources Forest Access Road along the northern shore of Lobstick Bay of Lake of the Woods, east of Highway 71. As of August 1983, the road extended to the creek flowing into the northern end of Mushkasu Lake. The southern portion of the area may be reached by boat from Dogpaw Lake and Caviar Lake. The northern portion is accessible from Dryberry Lake which can be reached by boat, and from Dirtywater Lake which is aircraft accessible.

Mineral Exploration

Gold has been the focus of exploration in the Lake of the Woods region since the turn of the century and many mines and prospects exist. In conjunction with the activity in the Cameron Lake area and southern Dogpaw Lake area, exploration for gold has increased in the current map area in the last 2 years.

In 1948 and 1949 Grand Chibougamau Mines Limited explored 9 claims on Caviar Lake southwest of Hope Lake. Stripping, trenching, and sampling were carried out on northeast- and northwest-trending silicified-carbonatized shear zones on the mainland south of Martin Island in the northeastern corner of western Caviar Lake. Assay results reported from trenches on the northeast-trending shear zone ranged from 0.01 to 0.60 ounce gold per ton; trenches on the northwest-trending shear zone were reported to contain trace to 0.06 ounce gold per ton (Assessment Files Research Office, Ontario Geological Survey, Toronto (AFRO)).

In 1969, Canadian Nickel Company diamond drilled 2 holes in the Dirtywater-Warclub Lakes area; minor pyrrhotite, pyrite, and chalcopyrite were noted in schistose intermediate metavolcanics. Geologic mapping by Chester Kuryliw, Consulting Geologist, was carried out in 1973 on a claim group that included part of the map area on the eastern side of Dogpaw Lake (AFRO).



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

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[1] Geologist, Precambrian Geology Section, Ontario Geological Survey, Toronto

Selco Mining Corporation Limited (Selco Incorporated) explored a large area between Sioux Narrows and Dryden from 1978 to 1980. In 1978 an INPUT(R) airborne electromagnetic survey was flown, and in 1979 claim groups along Dirtywater Creek, Warclub Lake, and Dogpaw Lake had ground magnetic and electromagnetic surveys completed on them. In 1980, 2 diamond-drill holes were drilled to check anomalies in the northwestern corner of Dogpaw Lake (AFRO).

During the 1983 field season various firms and individuals prospected within the map area. Current claims are held in the Caviar Lake area by Labrador Mining and Exploration Company Limited, Gus Kowalski, and Roy and Jack Martin, and east of Kishquabik Lake by Labrador Mining and Exploration Company Limited.

General Geology

The area was previously mapped by Burwash (1934). The Cedartree Lake area south of the map area was mapped by Davies and Morin (1976), and the area to the east was mapped by Davies (1973). The area to the west has had recent mapping completed by the author (Johns and Richey 1982; Johns and Davison 1983a, 1983b).

Except for the Late Precambrian northwest-trending diabase dike, the rocks exposed in the map area are Early Precambrian (Archean) in age.

As noted previously (Johns 1982) in the Long Bay area, 2 separate geological environments are separated by the Pipestone-Cameron Fault. The fault is present in the southwestern portion of the map area; only a portion of the Snake Bay Formation is exposed to the southwest of it. The majority of the area lies northeast of the fault.

The rocks exposed northeast of the Pipestone-Cameron Fault are subdivided into 3 metavolcanic-metasedimentary units. The oldest unit, comprising mafic metavolcanic flows with pillows, pillow breccia, hyaloclastite, and mafic pyroclastic rocks, has been named the "Populus Volcanics" by Trowell *et al.* (1980). In the Dogpaw Lake area, these mafic metavolcanics are interbedded with intermediate pyroclastic rocks, flows, and flow breccias. Due to the proximity of the Pipestone-Cameron Fault, the relationship between these mafic and intermediate metavolcanics is obscure. Mafic flow breccias, pillow breccias, hyaloclastites, and pyroclastic rocks predominate in the Dogpaw Lake area and grade northeastwards into massive and pillowed flows with interbedded intermediate and mafic pyroclastic rocks.

Overlying the Populus Volcanics are interbedded metawackes and intermediate metavolcanics referred to as the Warclub Group (Johns and Davison 1983a, 1983b). Although feldspathic wackes are the predominant rock type within the Warclub Group, intermediate tuffs are common along Dirtywater Creek. The metawackes have been disturbed by intrusion and metamorphic effects of the Kishquabik Lake Stock.

The Berry Complex (Johns 1981; Johns and Richey 1982; Johns and Davison 1983a, 1983b) pinches out and becomes infolded within the Warclub Group. Pyroclastic rocks and quartz-feldspar porphyry are the predominant rock types of the Berry Complex within the map area. These rocks also have been highly metamorphosed and disturbed by the intrusion of the Kishquabik Lake Stock.

Gabbro and diorite sills have intruded the mafic metavolcanics of the Populus Volcanics and may in fact be coeval. Within the Warclub Group and Berry Complex are thin mafic dikelets and sills which are generally highly sheared, contorted, and boudinaged. Differentiated ultramafic to mafic sills intrude the Warclub Group between Dirtywater Creek and Dryberry Lake. These sills can be traced from the eastern edge of the map area west for 8 km.

Feldspar porphyry and quartz-feldspar porphyry dikes and sills intrude the Warclub Group and the ultramafic-mafic sills, and to a lesser extent the Populus Volcanics.

Intrusive rocks of the Dryberry Batholith occur on the shore and islands of Dryberry Lake. Pink, medium-grained, equigranular, biotite granodiorite with associated pink to white pegmatite sills and dikes are the most common rock types. On the peninsula separating the main western portion of the lake from the eastern portion, very coarse grained, white, muscovite-quartz-myrmekite pegmatite dikes and sills are very extensive. They intrude amphibolite, gabbro, and metasedimentary gneisses.

The Kisquabik Lake Stock is a late, high-level porphyritic stock which has forcefully intruded the Warclub Group and the Berry Complex. This stock is relatively homogeneous, medium- to coarse-grained, plagioclase phyric monzodiorite. A biotite diorite associated with the stock is found along the southwestern margin. A zoned high-level stock studied by Heimlich (1966) is centred on Hope Lake in the southeastern part of the area. This stock has a monzonite core and is rimmed by quartz monzonite and granite. The southern end of the stock consists of a foliated, altered granite.

Structural Geology

The Populus Volcanics have an easterly strike in the area around Dogpaw Lake and then trend to the northeast. The Warclub Group has been deformed around the Kishquabik Lake Stock and then trend northeast in the vicinity of Warclub Lake. The Populus Volcanics generally face northwest, and the Warclub Group rocks exposed on Dirtywater Lake also face in a northerly direction. Thus it appears that the Warclub Group overlies the Populus Volcanics.

The rocks along the contact between the Populus Volcanics and Warclub Group are highly schistose to sheared. This zone of shearing and carbonatization can be traced through Lobstick Bay where it merges with the Pipestone-Cameron Fault. The author proposes that the Wabigoon Fault on Chart A of Trowell *et al.* (1980) be extended southwest into the present map area to intersect with the Pipestone-Cameron Fault. Rocks in the Pipestone-Cameron Fault Zone are highly sheared and carbonatized and can be traced southeast through Dogpaw Lake.

Many local top reversals in the Lobstick Bay region and along the contact between the Warclub Group and Populus Volcanics indicate the presence of tight isoclinal folding. This appears to be the result of the forceful intrusion of the Kishquabik Lake Stock. The Warclub Group rocks exposed between Dryberry Lake and the Kishquabik Lake Stock occur in a syncline whose axis parallels Dirtywater Creek. In the Dogpaw Lake area units trend northwesterly through northerly to easterly as a result of movement along the Pipestone-Cameron Fault.

The supracrustal rocks throughout the map area are generally foliated to schistose. Only the massive mafic flows are exceptions to this. The porphyritic monzodiorite of the Kishquabik Lake Stock is mainly massive, although portions have developed a weak foliation.

Economic Geology

The northern Lake of the Woods area, the Atikwa-Kakagi Lakes area, and Cameron-Rowan Lakes region which flank the present map area contain many gold occurrences and prospects as well as a number of past producers. The Regina Mine on Regina Bay, Lake of the Woods, 13 km west of the present area, produced over 8000 ounces of gold and 1460 ounces of silver before it closed (Beard and Garratt 1976). The Gaudry Occurrence, also 13 km west of the present map area, is located east of the Sioux Narrows Provincial Park along the northern contact of the Regina Bay Stock, and is situated on a silicified-carbonatized shear zone. Two silicified-carbonatized shear zones were examined by Grand Chibougamau Mines Limited south of Martin Island on Caviar Lake and they reported gold values of up to 0.60 ounce gold per ton (AFRO). The northeast-trending shear zone was reported to have higher values than the northwest-trending shear zone.

Many rusty shear zones and carbonatized shear zones found within the Populus Volcanics were grab sampled by the field party and assayed by the Geoscience Laboratories, Ontario Geological Survey, Toronto. All the carbonatized, pyritized, and massive pyrite samples assayed returned less than 0.01 ounce gold per ton.

Numerous electromagnetic conductors have been examined in the map area (AFRO). These conductors occur within the Warclub Group and appear to be the result of mineralized graphitic horizons. Grab samples of rusty shear zones, pyritiferous shear zones, and massive pyrite that were assayed for gold had a qualitative ICP-spectrometric analysis carried out on them by the Geoscience Laboratories, Ontario Geological Survey, Toronto, and commonly contained traces of copper, lead, nickel, and zinc. Traces of chalcopyrite were noted within massive and pillowed portions of the Populus Volcanics.

Potential for economic gold mineralization within the map area is high. The Nuinsco Resources Limited's Cameron Lake Deposit is located within sheared, silicified, highly carbonatized mafic metavolcanics just north of the Pipestone-Cameron Fault. Sheared, highly carbonatized mafic metavolcanics are associated with the Pipestone-Cameron Fault on Dogpaw Lake and should be examined for their gold potential. Many narrow silicified-carbonatized shear zones cutting the mafic flows of the Populus Volcanics around Caviar Lake may also host gold mineralization. The mafic metavolcanics between Hope Lake and the Kishquabik Lake Stock are also highly sheared. This shearing, combined with the nearness of the stock providing a heat source for circulating fluids, may be indicative of a good environment for the deposition of gold and possibly base metals similar to the Maybrun Mine.

The Maybrun Mine, located in the Atikwa Lake area (Davies 1973), is a copper-gold deposit within mafic pillow lavas. The potential exists for similar mineralization within the Populus Volcanics.

Many thick, massive pegmatites are found intruding the supracrustal rocks along the southern shore of Dryberry Lake. These pegmatites should be prospected for their mineral potential.

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No. 3 Lithophile Mineralization in the Dryden Pegmatite Field

F.W. Breaks[1]

Introduction

This special project focuses on the Dryden Rare-Metal Pegmatite Field, presenting further information on petrological-geochemical characteristics of mineralization in a study that was initiated in 1980 (Breaks 1980).

Five weeks were spent in the field with emphasis on the following:

1. completion of detailed mapping of individual pegmatites
2. completion of mineralogical and bulk geochemical sampling of pegmatites
3. detailed geochemical studies on endogenic dispersion anomalies adjacent to rare-metal-bearing pegmatites
4. examination of scheelite mineralization in Brownridge and Zealand Townships to study the association of tungsten with the surrounding rare-metal-bearing pegmatites

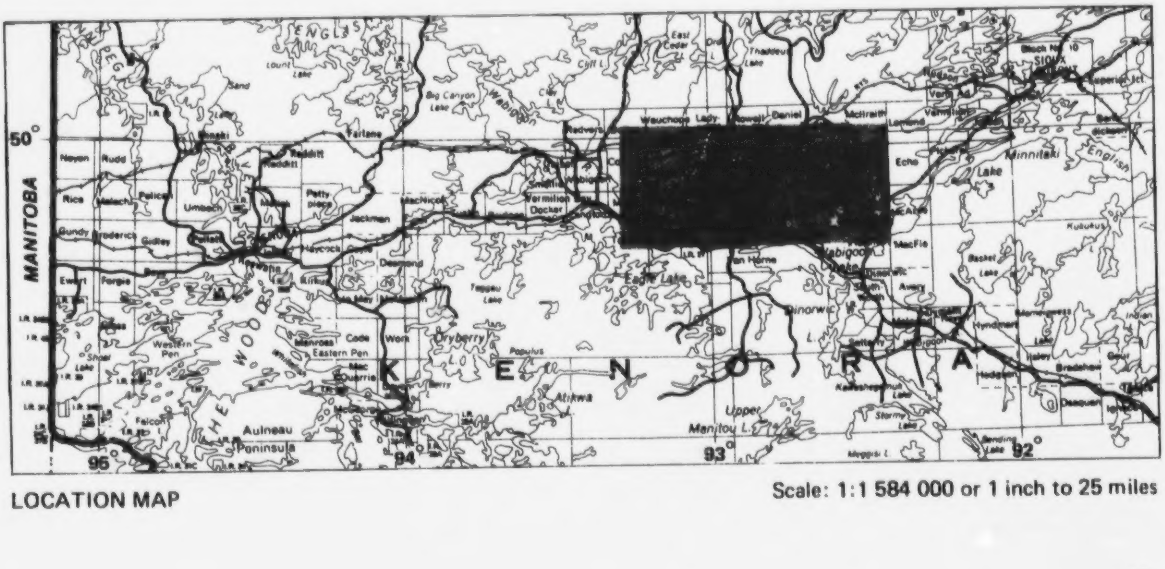
This project also comprises part of a Ph.D. dissertation currently being undertaken by the author at Carleton University, Ottawa, Ontario. All geochemical and X-ray diffraction mineralogical identification data in this report are based on analyses by the Geoscience Laboratories, Ontario Geological Survey, Toronto.

Previous Work

Early field work in this area was performed by Moorhouse (1941), Satterly (1943), and Harding (1951). More recent work at reconnaissance and detailed scales has been published by Breaks, Bond, Westerman, and Harris (1976), Breaks, Bond, Harris, Westerman, and Desnoyers (1976), Breaks, Bond, and Stone (1978), and Page and Christie (1980).

Mineral Exploration

The first record of lithophile mineralization in the region was by Burwash (1939) who briefly described cassiterite associated with tourmaline pegmatite on Portage Bay of



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

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Eagle Lake. Satterly (1943, p.55) mentioned an occurrence of beryl in Zealand Township, probably the Taylor Beryl Occurrence of this report. Mineral exploration for lithophile elements, however, occurred mainly during 2 periods:

1. from 1955 to 1964 for lithium
2. from the late 1960s to the present for tungsten and tantalum

Discovery of spodumene pegmatites near Mavis Lake, Brownridge Township, in 1956, led to their investigation by Lun-Echo Gold Mines Limited.

In 1964, A. Kozowy and A. Leduchowski discovered a spodumene-pollucite-bearing complex pegmatite near Tot Lake. J. Donner investigated the mineralization by geological mapping and magnetometer survey, and diamond drilled 4 holes totalling 732 feet (Assessment Files Research Office, Ontario Geological Survey, Toronto (AFRO). In 1973, A. Kozowy did a limited amount of trenching.

In the late 1960s, tungsten mineralization was discovered by D. Petrunka near Sharpe Lake in Brownridge Township and initial evaluation was undertaken by Noranda Mines Limited (Blackburn and Hailstone 1983). Currently, a block of 32 claims is being assessed under option agreement by Sanmine Exploration Incorporated who, in 1981, commenced a program of surface exploration and limited diamond drilling.

Interest in the tantalum potential of rare-metal-bearing pegmatites of the Dryden area began in 1979 when Selco Incorporated carried out geological mapping, diamond drilling, and a lithium lithogeochemical survey in the Mavis Lake spodumene pegmatite (AFRO). In 1979, the Tantalum Mining Corporation of Canada Limited acquired the property containing the Tot Lake complex rare-metal pegmatite and undertook a limited diamond drilling program (AFRO). In 1980, property containing the Gullwing Lake complex rare-metal-bearing pegmatite was optioned from A. Kozowy by Selco Incorporated and Dome Exploration Canada Limited. Both options are now terminated.

Tantalum Mining Corporation of Canada briefly optioned the Fairservice Property in 1982 (AFRO).

Regional Pegmatite Zonation

The geological interpretation of the regionally zoned pegmatite sequence, initially delineated in the Dryden area by Breaks (1980, p.6), has been modified to accommodate new data. As indicated in Table 1, 2 chemically and mineralogically distinct subfields have now been recognized. The Mavis Lake and Gullwing-Tot Lakes Subfields lie approximately 9.7 km apart, and it remains to be determined whether these 2 areas of known rare-metal mineralization are physically connected or genetically related. This report deals mainly with the Mavis Lake Subfield. Work on the Gullwing Lake-Tot Lake Subfield will be released at a later date (Breaks in preparation).

Mavis Lake Subfield

This rare-metal-bearing pegmatite subfield is confined to the northern limb of the west-plunging Thunder Lake Syncline, delineated by Satterly (1943). Dimensions of the subfield, which trends 090° to 105°, are 8 km in strike length by between 0.8 and 1.4 km in width. Petrological and geochemical features of this subfield are summarized in Table 1. Noteworthy is the change in both primary mineralogical assemblages and degree of albitization in a west to east direction.

Pegmatites of the Mavis Lake Subfield are interpreted to have originated from a highly fractionated phase of the Ghost Lake Batholith, typified by outcrops at the eastern end of the Dryden Airport runway. The Zealand Stock, isolated in the core of the Thunder Lake Syncline, contains similar rocks and probably represents a phacolithic apophysis of the batholith, which is corroborated by high (10 to 327 parts per million (ppm) tin values in both masses.

Most spodumene pegmatites in the Mavis Lake Subfield are confined to the Fairservice Property and occur in 3 specific areas, herein termed the Main, South, and East Zones. Detailed mapping by Pryslak (1981) and the writer has delineated 16 distinct pegmatite lenses, which are generally concordant to host rock foliation at surface. Contacts, however, undulate in vertical sections as evidenced by direct observation and by diamond drilling (A. Pryslak, Selco Incorporated, personal communication, 1981). Dimensions of most significant pegmatite lenses vary between 60 and 270 m in strike length, and widths of 3 to 25 m.

Internal zonation within individual Mavis Lake Subfield pegmatites is only crudely developed and is commonly obscured by albitization. The best example of internal zonation is provided by the Pegmatite No. 1 from the Main Zone of the Fairservice Property. This 12 by 76 m, Li-Be-Ta-Nb-bearing pegmatite contains the following successively fractionated zones:

1. potassic feldspar-enriched spodumene pegmatite
2. spodumene-enriched albite-quartz pegmatite
3. quartz-rich core

The quartz-rich core is discontinuously developed and typically, although not strictly, confined to the central part of the pegmatite. This zone comprises approximately 70 to 80% quartz with ancillary amounts of beryl, light-green spodumene, blocky K-feldspar (which may contain associated tantalite), green muscovite, and blue apatite. Secondary minerals related to late stage albitization include albite as coronas around spodumene, orange manganiferous garnet, lime-green sericite, and tourmaline.

The enveloping spodumene-enriched pegmatite contains the highest concentrations of spodumene observed

TABLE 1 PETROLOGICAL AND GEOCHEMICAL FEATURES OF RARE-METAL-BEARING PEGMATITES FROM THE DRYDEN FIELD

AREA/OCCURRENCE	PEGMATITE STRUCTURE	CHARACTERISTIC PEGMATITE MINERAL ASSEMBLAGE[1]	GEOCHEMICAL ASSOCIATION[2]	DEGREE OF LATE STAGE REPLACEMENT ALBITIZATION
Mavis Lake Subfield				
Dryden Airport Occurrence, Zealand Township	Unzoned, internal, usually barren potassic pegmatites	Garnet + Muscovite + Tourmaline + Albite + Quartz + Blocky K-feldspar + (Limegreen Beryl)	B-(Be)	Absent
Taylor Occurrence, Concession VII, Zealand Township	Unzoned potassic pegmatites developed marginal to Ghost Lake Batholith	Beryl + Tourmaline + Albite + Quartz + Graphic K-feldspar + Blocky K-feldspar + (Columbite + Garnet + Muscovite + Green Apatite)	B-Be-(Sn-Nb>Ta)	Incipient. Small pods of fine-grained, saccharoidal aplite (± Chromium Mica + Quartz + Albite)
Petrunka Occurrence, Brownridge and Zealand Townships	Unzoned, tourmaline-enriched fracture/pillow selvedge-controlled replacement in Brownridge mafic metavolcanics	Quartz + Plagioclase + Biotite + Scheelite + Tourmaline + (Pyrite + Holmquistite + Fluorite?)	W-B-F-(Li-Sn)	Not Observed
Fairservice Property, Brownridge Township				
Main and South Zones	Unzoned to crudely zoned external pegmatites. Contains randomly oriented, green primary spodumene phenocrysts (Type 1 spodumene of Heinrich 1975)	Beryl + Green Muscovite + Albite + Spodumene + Blocky K-feldspar + Quartz + (Blue Apatite + Garnet + Tourmaline + Tantalite)	Li-Be-Ta>Nb-B-(Sn-Rb)	Moderate development of albitization (± Garnet ± Tantalite + White Beryl + Green Muscovite + Quartz + Cleavelandite)
East Zone	Unzoned external pegmatites	Primary mineralogy largely replaced. Remnants of blocky K-feldspar, spodumene, and quartz still discernible	Ta>Nb-Be-(Li)	Pervasive albitization. Most of pegmatite replaced by + White Beryl ± Tantalite + Green Muscovite + Quartz + Cleavelandite
Gullwing Lake-Tot Lake Subfield				
Mica Point Gullwing Lake, Drope Township	Crudely zoned, external potassic pegmatite	Muscovite + Biotite + Albite + Quartz + K-feldspar + (Molybdenite + Columbite-Tantalite)	Nb>Ta?-(Mo)	Incipient
Gullwing Lake Pegmatite, Webb Township	Complex external pegmatite. Most of dike consists of muscovite-biotite pegmatitic granite. Contains green Type 1 spodumene of Heinrich (1975)	Green Spodumene + Muscovite + Albite + Quartz + Blocky K-feldspar Albite + Green Muscovite + Quartz + Blocky K-feldspar	Li-Ta>Nb-(Mo-Sc)	Moderate albitization developed in 2 stages: 1. early medium-grained, equigranular ± biotite ± Tantalite + Muscovite + Quartz + Albite 2. later, fine-grained Lepidolite-Albite Complex ± Tantalite ± Beryl ± Garnet ± Lepidolite + Muscovite + Cleavelandite)

TABLE 1 PETROLOGICAL AND GEOCHEMICAL FEATURES OF RARE-METAL-BEARING PEGMATITES FROM THE DRYDEN FIELD (continued)

AREA/OCCURRENCE	PEGMATITE STRUCTURE	CHARACTERISTIC PEGMATITE MINERAL ASSEMBLAGE[1]	GEOCHEMICAL ASSOCIATION[2]	DEGREE OF LATE STAGE REPLACEMENT ALBITIZATION
Coates Pegmatite, Webb Township	Unzoned, external potassic pegmatite	Muscovite + Albite + Quartz + Graphic K-feldspar + (Molybdenite + Pyrite + Garnet + Samarskite + Sphalerite + Chalcopyrite + Beryl)	Mo-(Nb>Ta)	Incipient replacement by fine-grained albite along edges of K-feldspar. Most molybdenite and samarskite associated with albitized areas
Pegmatite 215 m Southwest of Coates Pegmatite, Webb Township	Unzoned, external potassic pegmatite	Muscovite + Albite + Quartz + Blocky K-feldspar + (Columbite-Tantalite + Garnet + Molybdenite)	Nb>Ta?-(Mo)	Incipient, film-like albitization and associated columbite-tantalite in coarse blocky K-feldspar
Tot Lake Pegmatite, Webb Township	Complex external pegmatite. Contains pink Type 2 spodumene of Heinrich (1975)	Pink Spodumene + Pollucite + Quartz + Albite + Blocky K-feldspar + (Fluorapatite + Garnet + Tourmaline)	Li-Cs-Rb-Ta>Nb-Be-F-P	Extensive albitization developed in 2 stages: 1. saccharoidal sodic aplite (Blue Apatite Tourmaline + Quartz + Albite) 2. Lepidolite-Albite Complex (± White Beryl ± Garnet ± Tantalite + Sericite + Lepidolite + Quartz + Cleavelandite)

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[1] Accessory minerals placed in brackets.
[2] Minor elements placed in brackets.

in the Mavis Lake Subfield, and also have relatively high quartz contents (Table 2). The K-feldspar-enriched spodumene pegmatite is the outermost primary zone that is recognizable, and tends to be asymmetrically distributed in Pegmatite No. 1. This zone features markedly lower spodumene contents relative to the above-mentioned unit. Petrologically, the K-feldspar-rich pegmatite is characterized by spodumene-quartz symplectites typically enclosed by a thin shell of quartz and green muscovite, all of which are enveloped by a coarse K-feldspar aggregate. This unit appears in several lenses of the Main Zone, but typically contains very little columbite-tantalite.

Replacement Stage Albitization and Endogenous Geochemical Aureoles

The degree of late-stage albitization increases from west to east in the subfield such that thin (1 to 3 m wide) pegmatite sheets, exposed at the East Zone of the Fairservice Property, consist essentially of secondary mineral assemblages, mainly white sodic beryl + green muscovite + quartz + cleavelandite ± tantalite. Primary relict spodumene, largely converted to "cymatolite", ragged blocky K-feldspar, and quartz are, nevertheless, still recognizable. Farther west, at the Main Zone, albitization is much less pronounced. In many places, there the albitization appears directly related to a quartz-rich core as in Pegmatite No. 1.

Metasomatic release of Li, Cs, Sn, B, Rb, and F from albitized spodumene pegmatites is responsible for the formation of secondary biotite, tourmaline, and holmquistite which are intensely developed within layers and pods in proximal mafic metavolcanic host rocks (e.g. the Main and South Zones of the Fairservice Property). Two analyses of these assemblages from immediate contact areas around spodumene-beryl-tantalite and columbite-beryl pegmatites, respectively, are presented in Table 3.

Be, Cs, F, Li, Rb, and Sn are all useful in lithogeochemical surveys, however, in reconnaissance surveys designed to locate rare-metal-bearing pegmatite fields, lithium represents the element of greatest utility (Ovchinnikov 1976). Pryslak (1981) documented several impressive lithium aureoles in the Main Zone; the largest measures 60 to 185 m by 1220 m and contains maximum lithium concentrations of 4095 parts per million (ppm).

Tungsten Mineralization

Recent work by Sanmine Exploration Incorporated in Brownridge and Zealand Townships has identified scheelite mineralization over a 1525 by 488 m area (R. Redmond, Consulting Geologist, personal communication, 1983). This zone, which parallels the 095° trend of the Brownridge Volcanics/Zealand Sediments contact described by Satterly (1943), is situated within the beryl-bearing pegmatite zone.

TABLE 2 **MODAL ANALYSES IN VOLUME PERCENTAGE OF ZONES FROM SPODUMENE PEGMATITE NO. 1, FAIRSERVICE PROPERTY[1]**

Spodumene	Quartz	K-feldspar	Albite	Green Muscovite	Sericite	Beryl
ALBITE-SPODUMENE-QUARTZ PEGMATITE						
29.4	47.3	5.0	8.8	3.8	5.0	0.8
48.7	37.4	—	6.8	7.1	—	tr
K-FELDSPAR-RICH SPODUMENE PEGMATITE						
6.7	23.2	54.6	12.9	2.6	—	tr

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[1] Modes done over 2 by 4 m area on 20 cm grid
tr = Present in trace amounts

Scheelite mineralization occurs mainly in amphibolitized, pillowed mafic metavolcanics, and sulphidic horizons. Massive mafic flows occur on the property, but generally do not appear to be favourable hosts for scheelite, which has so far been found in 2 geological situations:

1. in calcsilicate pods and layers contained within the deformation fabric of host rock
2. in tourmaline-rich sheets up to 0.3 m thick which variably transect foliation trends

The calcsilicate domains contain relatively low levels of scheelite.

The highest concentrations of scheelite occur in flat-lying (11° to 19° dip), undulating biotite-tourmaline-rich sheets, which also contain minor quartz, plagioclase, pyrite, and rare holmquistite. This assemblage is also developed along several ancillary fracture sets and along pillow selvages, which have undergone intense replacement by tourmaline and biotite. Scheelite, which forms anhedral poikilitic crystals up to 5 by 7.5 cm, appears honey-brown on clean weathered surfaces.

Analysis of a 3.5 m channel sample obtained from a flat-lying biotite-tourmaline sheet with an obvious high scheelite content is given below (in parts per million (ppm) unless otherwise stated):

W	Be	Cs	F	Li	Sn	Au
950	45	40	9600	246	193	<2 ppb

The levels of tungsten are similar to those previously documented by Noranda Mines Limited who reported channel samples of up to 0.1% WO_3 (Blackburn and Hailstone 1983, p.12-13) and Selco Incorporated who obtained grades up to 0.09% WO_3 (A. Pryslak, Geologist, Selco Incorporated, personal communication, 1983).

The occurrence of scheelite has also been verified by this survey within the Main and East Zones of the Fairservice Property. At the Main Zone, low quantities of scheelite are disseminated within axinite-bearing calcsilicate pods and layers situated up to 1 m from spodumene pegmatite. The East Zone contains sporadically distributed scheelite associated with albite-tourmaline veinlets connected with albitized spodumene pegmatite sheets. This establishes that tungsten mineralization is consanguineous, at least with tourmaline-rich sheets associated with rare-metal pegmatites, as also suggested by the association of tungsten with anomalous trace levels of rare metals Li, Cs, and Be, and Sn and F in tourmaline-rich sheets at the Petrunka Occurrence. Sporadic holmquistite occurrences attest to the presence of lithium in the fluorine-boron-rich fluid system.

Suggestions for Future Exploration

The wide, but thus far sporadic occurrence of scheelite in the Mavis Lake Subfield suggests that further exploration should be undertaken, especially on the Fairservice Property and the area to the east. If continuity can be demonstrated between all known scheelite occurrences, a tungsten belt at least 6100 m in strike length will add to the economic attraction of the area.

Tourmaline appears to represent a reasonable prospecting guide because of its common association with scheelite in the study area and on a global basis. Charoy (1982) suggested that this association is due to the role of boron in transport of tin and tungsten.

Special attention should be paid to plagioclase-biotite-tourmaline sheets, such as those found at the Petrunka Occurrence, and the East Zone of the Fairservice Property, especially where they are associated with replaced pillow selvages. This suggests the introduction of a phase potentially containing tungsten and associated rare metals. Calcsilicate domains, also widespread in the Brownridge Volcanics, should be examined for scheelite.

The possibility of tantalum-niobium mineralization in skarn assemblages in the Dryden area also should be investigated; Kudrin *et al.* (1967) described tantalum-niobium-beryllium mineralization in pyroxene-garnet-scapolite-vesuvianite skarns from Siberia which contains scheelite and molybdenite.

TABLE 3 **SELECTED CHEMICAL ANALYSES OF METASOMATIC GLIMMERITE DEVELOPED AT CONTACTS OF SPODUMENE- AND BERYL-BEARING PEGMATITES FROM MAVIS LAKE SUBFIELD (in parts per million)**

	B	Be	Cs	F	Li	Rb	Sn	Ta	Nb	K
PEGMATITE NO. 2, FAIRSERVICE PROPERTY (tourmaline-holmquistite-biotite glimmerite)	450	22	920	7650	3050	3790	680	<30	13	3.69%
PEGMATITE NO. 2, TAYLOR BERYL (biotite-rich glimmerite)	5	20	N.D.	7250	2300	2210	762	<30	70	4.58%

N.D = Not Determined

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No. 4 The Sturgeon Lake Gold Area

P.C. Thurston[1]

Introduction

This project is designed to place some of the Sturgeon Lake gold occurrences into a regional geological context. The area of interest lies between Sturgeon Narrows and Horizontal Bay of Sturgeon Lake, i.e. along the western shore of northern Sturgeon Lake. The area is bounded by Latitudes 50°05′N to 49°57′N, and Longtitudes 90°45′W to 91°00′W. Access to the area is via a logging road network which branches off Highway 599 about 32 km south of Savant Lake. The road network is locally known as the Six Mile Lake Road. The most recent mapping is that of Trowell (1983a, 1983b) completed in the early to mid-1970s. This mapping was designed to cover some poorly known parts of the latter area in reconnaissance fashion, using the road network and major lakes.

Mineral Exploration

Exploration in the general area began at the turn of the century, with intense prospecting activity described by Moore (1911) resulting in the productive period at the Saint Anthony Mine (1905 intermittently until 1941) with production of 63 310 ounces of Au, and 16 341 ounces of Ag (Trowell 1983a). A period of base-metal exploration in the late 1960s to 1970s led to production from 3 orebodies (Trowell 1983a), the Lyon, Boundary, and Mattabi Deposits.

A recent resurgence in gold exploration has been described in the Northern Miner (Cunningham 1983) involving major and minor exploration companies. The activity was sparked by the Steep Rock Mines Limited optioning of the Armstrong-Best showing north of King Bay, Sturgeon Lake. This showing is in blue quartz veins cutting feldspar porphyry and epidotized mafic metavolcanics. At present, several hundred claims are in good standing.

In addition to the early activity, in 1971 Canadex Resources examined a sulphide-carbonate zone in mafic metavolcanics at Sturgeon Narrows and encountered some gold values.

In 1974, Falconbridge Limited examined an auriferous syenite dike at Sturgeon Narrows with poor results.

In 1980 and 1981, Sherritt Gordon Mines Limited examined several gold properties in the area.

There has been recent exploration on the properties of Kerr Addision Mines Limited, C. Kuryliw, W.G. Wahl, and several others (Cummingham 1983).

General Geology

All bedrock in the area is Early Precambrian (Archean) in age. The area (Figure 1) includes part of the Wabigoon Subprovince granite-"greenstone" terrane. The supracrustal units seen on the Six Mile Lake Road from north to south are described in the following sections:

1. Coarse-grained pillowed and massive amphibolites of the hornblende hornfels facies are adjacent to the granitic batholith exposed to the north and east.
2. A felsic pyroclastic unit about 1400 m thick extends for 12 km along strike from Highway 599 in the west almost to King Bay of Sturgeon Lake. The unit exhibits, over the full thickness, a generally fining upward aspect, with tuff-breccia gradually fining to predominantly tuff. Individual depositional units, defined by fine tuffaceous tops, exhibit normal size grading over typically 30 to 100 m thicknesses, with the proportion of pumice increasing upward. Grading of clast size and type, the lack of bedding, abundance of pumice, and sequence of primary structures suggests the unit represents subaqueous ash flows (Parsons 1969). The above parameters, especially the well developed grain gradations in tuffaceous units, indicate a northerly top direction for this unit.
3. A unit of mafic flows with massive, pillowed, and plagioclase-phyric flows and associated hyaloclastite extends the full width of the area. The flows exhibit varied, generally slight degrees of epidotization, silicification, and carbonatization. Principal areas of carbonatization are immediatiely north and south of King Bay of Sturgeon Lake. Epidotization of hyaloclastic mafic flows is prominent immediately north of the southern felsic unit, south of King Bay, and north of Dan's Lake. A major plagioclase-phyric unit occurs just south of unit 2 (described above) and north of unit 4 (described below). The northern occurrence includes, as well as plagioclase phenocrysts, some centimetre scale clots of felsic plutonic material.

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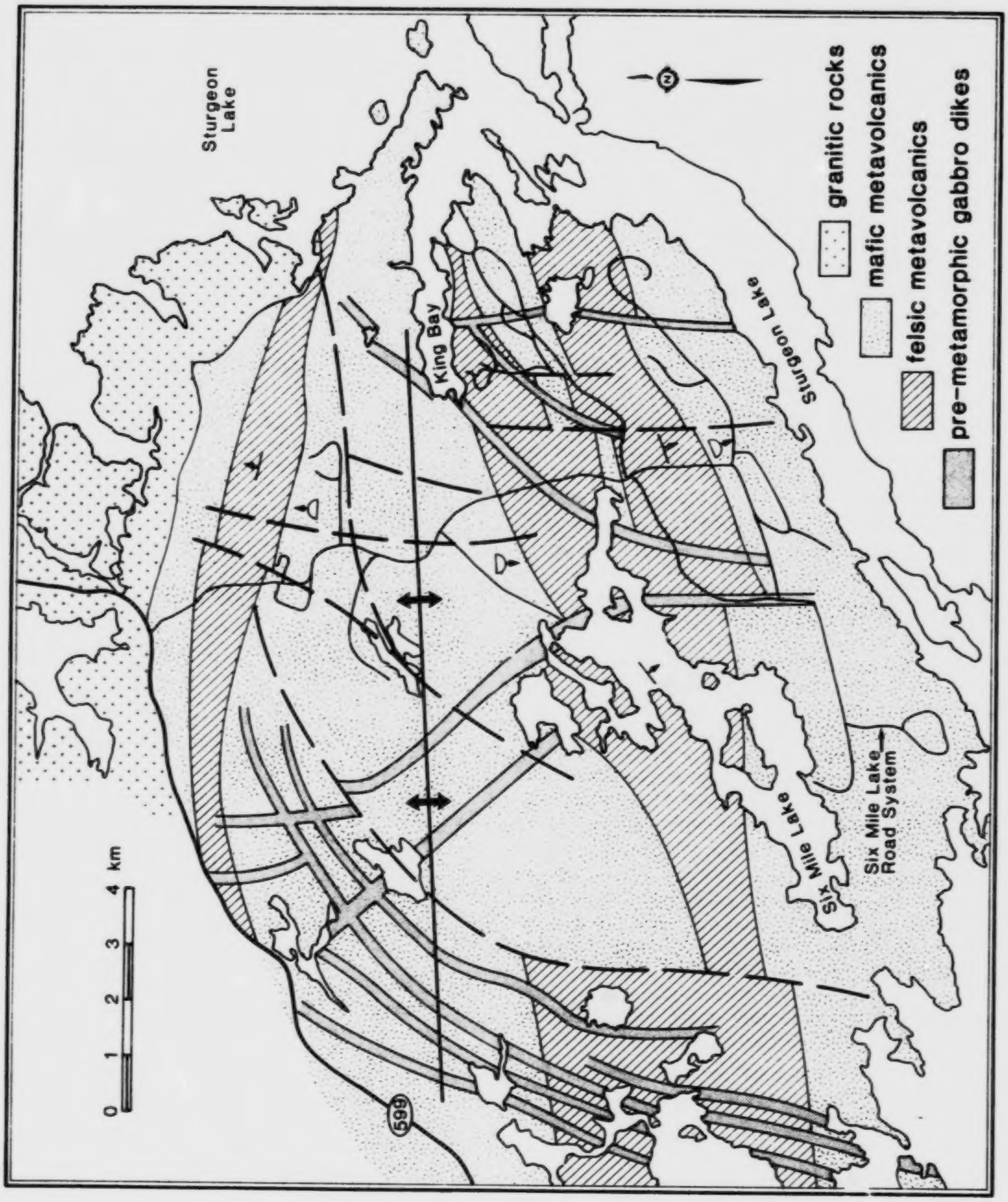
Sturgeon Lake
King Bay
Sturgeon Lake
Six Mile Lake
Six Mile Lake Road System
599
0
1
2
3
4 km
N
granitic rocks
mafic metavolcanics
felsic metavolcanics
pre-metamorphic gabbro dikes

Figure 1. Geological sketch map, central Sturgeon Lake area.

4. The southern felsic unit, termed the top of the Jumping-Six-Mile Lake Cycle by Trowell (1983a), is well exposed along the Six-Mile Lake Road and Cobb Bay of Sturgeon Lake. The unit consists of felsic ash flows generally 100 to 200 m thick, which gradually fine upward to tuffaceous tops. Compositional zoning from andesite-dacite to rhyolite is present within individual depositional units. The unit is capped by a 30 to 60 m thickness of cherty, thin-bedded felsic tuff. Generally, top indicators in this sequence suggest south-facing tops.
5. South of this is a sequence of mafic flows containing a prominent unit about 60 m thick with 1 to 5 cm plagioclase phenocrysts, succeeded to the south by pillowed, variably epidotized, and silicified mafic flows with rare felsic tuff interflow pyroclastic-epiclastic units.

The sequence is cut by pre-metamorphic north- to northeast-trending gabbro to diorite dikes which range from single phase to composite dikes. The dikes have chilled margins against the country rocks and chilled margins between phases. They range in width from miniscule to 150 to 250 m. They often comprise up to 30% of the crustal volume, particularly in areas underlain by felsic metavolcanics.

The area is cut by syn- to post-tectonic granitoid intrusions varying from trondhjemite to quartz monzonite.

Structural Geology

On the basis of the above facing data, the author concludes that the supracrustal rocks are folded about a central anticline. Therefore, the units above may be considered as parts of 2 mafic to felsic cycles. The lower cycle consists of a lower basaltic part (unit 3) with the upper felsic part being units 2 and 4 (above). Above this is exposed the mafic base of a younger cycle. The pre-metamorphic dikes, referred to above, fill cross-cutting fractures along which there has been minor amounts of north-south movement. The origin of these fractures is obscure.

Economic Geology

Trowell (1983b) describes 2 major types of gold mineralization in the area:

1. quartz veins cutting mafic metavolcanics
2. quartz veins cutting granitic intrusions

The following additional details are presented as a result of this investigation.

1. Quartz and quartz-tourmaline veins cut epidotized and/or silicified mafic and felsic metavolcanics in the Miner's Loop Road area at a showing on the northern side of the main road, and at the Darkwater Mine.
2. Quartz and carbonate veins cut carbonatized mafic metavolcanics on the Steep Rock Mines Limited Property on the southern shore of King Bay (Trowell 1983b, p.98-99).
3. Blue quartz veins cut sulphide facies ironstone on the southern shore of King Bay at the Steep Rock Mines Limited Property (Trowell 1983b, p.98-99)
4. Blue quartz veins are associated with the contact between granitic rocks and mafic metavolcanics at Rainbow Island.
5. Blue quartz veins are associated with shear zones in epidotized mafic metavolcanics at Rainbow Island (both Kuehner showing, *see* O'Flaherty showing *in* Trowell 1983b).
6. Porphyry dikes and sills occur at Sturgeon Narrows and on King Bay (Trowell 1983a).
7. Gold is associated with carbonate rocks (Mogan Island and Sturgeon Narrows).

Recommendations to the Prospector

Basalts that have been subjected to hydrothermal alteration may develop a mineral assemblage consisting of albite, epidote, pale tremolite-actinolite, and carbonate instead of albite and chlorite, resulting in the development of apple green to grey-white colouration. The colour change is apparent on weathered and fresh surfaces and preferentially develops at pillow margins and in hyaloclastic rocks. In a regional sense, this phenomenon accompanies gold occurrences at Red Lake (Pirie 1981) and Confederation Lake (Thurston 1981), as well as numerous other locales.

Basalts that have been subjected to silica-rich hydrothermal fluids will have quartz progressively fill vesicles, and interpillow spaces followed by silicification of pillow rims and pillow interiors (Gibson and Watkinson 1979). This is known to occur in proximity to gold deposits at Red Lake (i.e. the Austin tuff, Durocher and van Haaften 1982) and Cameron Lake.

Epidotization of basalts was observed between Dan's Lake and King Bay of Sturgeon Lake, along the northern shore of King Bay along Six Mile Lake Road at about km 8, and at the Steep Rock Mines Limited showing north of King Bay.

Silicification of basalts was observed on the Jumping Lake Road at the Pointer Lake showing and south of the King Bay Road.

Careful mapping of these 2 alteration types coupled with As and Sb geochemistry may reveal additional areas with high Au potential. All blue quartz veins and especially sulphide- or tourmaline-bearing veins associated with epidotized or silicified basalts, particularly in areas of high As, Sb, or humus Au, warrant further exploration. An essential step in evaluation of geochemical results should be careful mapping of alteration type, intensity, distribution, and structural features controlling distribution of vein systems.

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No. 5 Lakehead-Atikokan Compilation Project

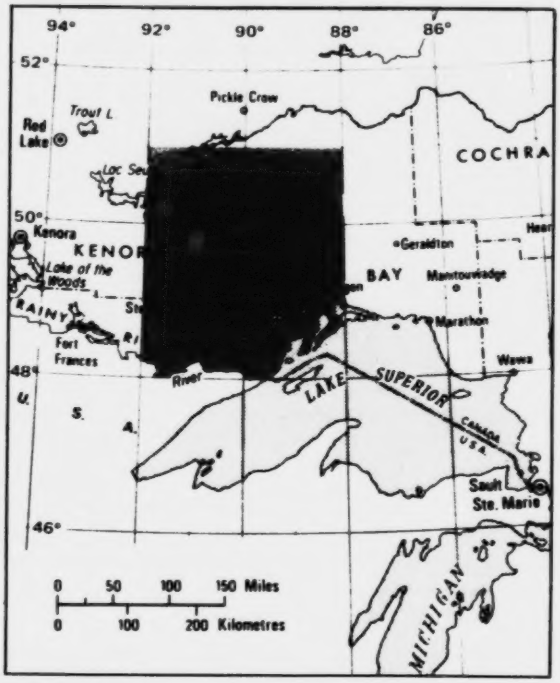
P.C. Thurston[1]

Introduction

The aim of this project is to produce a new edition of the Atikokan-Lakehead compilation map, first produced by the former Ontario Department of Mines in 1966 (Pye and Fenwick 1964). This revision will incorporate approximately 3 seasons of field work. When the original edition went out of print in the early 1970s, C.R. Kustra, then Resident Geologist, and John Scott, Resource Geologist at Thunder Bay, nearly completed a revision of the sheet. This revision, with an updating of the mineral occurrences produced by staff of the Thunder Bay Resident Geologist's office, will be published as a preliminary map in the near future.

The revised map, to be produced at the completion of this project, will be at a scale of 1:250 000, and boundaries will be revised to conform to the NTS system. Accordingly, boundaries for this project are the Canada-United States boundary to Latitude 50°00'N, and Longitudes 88°00'W to 92°00'W.

The area is traversed by the Trans-Canada Highway, both routes 11 and 17. Major subsidiary road systems include the lumber roads off Highway 527 (the Armstrong Road), and a network of concession roads north and south of Highway 17.



LOCATION MAP

Mineral Exploration

Recent mineral exploration has concentrated in areas of Early Precambrian (Archean) rocks. Numerous exploration programs for base metals have been carried out in the metavolcanic-metasedimentary belts. Producers of note have included the North Coldstream Mine at Burchell Lake, and the 3 orebodies at Sturgeon Lake (Mattabi, Boundary, and Lyon Lake). Iron ore was produced in the Atikokan area between the early 1940s and the early 1980s from Archean ironstone in the Wabigoon Subprovince. Gold exploration has occurred in the Archean supracrustal belts from the turn of the century onward. Production has occurred from deposits in the Atikokan, Thunder Bay and Lake Shebandowan areas. Production of Cr occurred in the 1920s from the Chrome Lake Occurrence in a pre-metamorphic ultramafic intrusion.

High-level Early Precambrian granitic rocks are host to several small-scale amethyst mines east of Thunder Bay.

Within the Proterozoic rocks in the Thunder Bay area, vein deposits of silver were mined from the 1870s to the turn of the century. Several iron occurrences in the Gunflint Formation have received exploration attention over the years.

The Cu-Ni deposit of Great Lakes Nickel Corporation Limited in Pardee Township occurs in an ultramafic intrusion of Proterozoic age.

Numerous occurrences of asbestos, fluorite, rare metals (Li, Cs, rare earths, Ta-Nb), Au, Ag, U, Fe, and Cr are known within the area.

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General Geology

Bedrock in the area ranges from Early Precambrian (Archean) age to Late Precambrian (Proterozoic) age. The Early Precambrian includes parts of the Abitibi (Wawa), Quetico, and the Wabigoon Subprovinces. Field work was concentrated this season in the Abitibi Subprovince.

In the Abitibi Subprovince, parts of 2 mafic to felsic cycles may be present in the area of Adrian and Conmee Townships. A structural dome in that area exposes pillowed mafic flows overlain by felsic flows and pyroclastic rocks, and possibly equivalent metasediments overlain by a second unit of pillowed mafic flows. The felsic unit may correlate with the Kaministikwia-Wild Goose felsic band (Kustra 1972), which extends from northern Conmee Township to the junction of Highways 527 and 17, east of Thunder Bay. Large parts of this sequence face north. Very preliminary facies analysis suggests the presence of felsic centres in the areas of Adrian Township north of Adrian Lake, and south of Highway 102 between Mokomon Lake and the Kaministikwia River. These suggestions are based respectively on the presence of felsic flows near Adrian Lake and a quartz-feldspar porphyry dome and proximal ash flows at Mokomon Lake.

The felsic metavolcanics near Highway 527 were deposited in a relatively proximal, subaerial environment based upon silicification of pumice fragments (Thurston 1980).

The previous compilation map shows several discontinuous lenses of metasediments with minor metavolcanics correlated with the Seine and Timiskaming Series. Limited evidence obtained thus far suggests these rocks were deposited in fault-bounded linear troughs. Rock types observed are: clast-supported polymictic normally graded conglomerate beds, 3 to 10 m thick, with 30 to 90 cm thick crossbedded arkoses and arenites; and amphibole-phyric mafic to felsic metavolcanics. The metavolcanics range from brecciated mafic flows of subaerial origin to debris flows and ash flows of more felsic composition. Limited textural evidence suggests all volcanic rocks observed in this sequence were deposited subaerially. Shegelski (1980) suggests a fluviatile origin for the metasediments. Plutonic rocks, possibly coeval with the Timiskaming-type metavolcanics, consist of bright red quartz-poor syenitic stocks. The unit extends continuously from Shebandowan Lake to Shabaqua Corners, and intermittently from Shabaqua Corners east to the Highway 527 area.

The Late Precambrian rocks in the area mapped consist solely of unmetamorphosed diabase dikes with a variety of trends.

Structural Geology

Work in the Abitibi Subprovince suggests the presence of a structural dome in Adrian and Conmee Townships west of Thunder Bay, based upon sparse facing data in the supracrustal rocks. Insufficient work has been done to define the structure in the remaining part of the Abitibi Subprovince west of Thunder Bay.

Suggestions to Prospectors

Felsic centres described above within the Abitibi Subprovince warrant further examination for base-metal mineralization. Some alteration (chloritization) occurs in the vicinity of the Adrian Township felsic centre. Detailed examination of the Ware Township felsic metavolcanics may be warranted. Any signs of alteration, presence of Cu or Zn sulphides, carbonatization, and development of chloritoid in the felsic metavolcanics mentioned above in Adrian and Ware Townships, is worth further examination for possible base-metal mineralization.

Stott and Schneiders (1983) have described the association of gold mineralization in the Shebandowan area with units which have undergone a second deformation. Lithologically, the bulk of the rocks deformed by a second deformation include the Timiskaming-type shoshonitic metavolcanics and metasediments. Therefore, the Timiskaming-type units to the east are a good exploration target for gold. On Highway 17 between Finmark and Shabaqua Corners, Archean pillowed basalts are extensively silicified and carbonatized with cherty interpillow spaces. Such hydrothermal alteration is a good target for gold exploration. Epidotization of pillowed mafic flows in central Ware Township on the Hazelwood Lake Road south of the microwave tower is another area with good potential for gold mineralization.

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No. S6 Geology of the Lumby Lake Area (Western Half), Districts of Kenora and Rainy River

M.C. Jackson[1]

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Introduction

This second year of a 2-year project (Jackson 1982) on the geology of the Lumby Lake area involved detailed (1:15 840 scale) mapping of the western half of the area. The 300 km² area is bounded by Longitudes 91°15′W to 91°30′W, and Latitudes 49°00′N to 49°07′30″N.

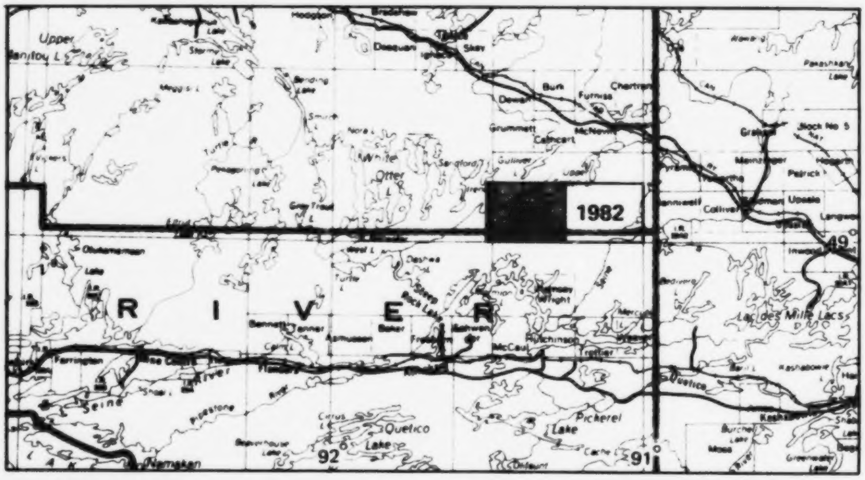
Access to the area is provided by a network of logging roads which can be reached by driving about 40 km north of Highway 11 on Highway 623 at Sapawe, 24 km east of Atikokan, or by driving south from Highway 17, 20 km west of Upsala, along the Firesteel River.

Mineral Exploration

Unless otherwise stipulated, the following information comes from the Assessment Files Research Office, Ontario Geological Survey, Toronto (AFRO).

Gold was first discovered in the Lumby Lake area in the late 1890s near Longhike Lake. This led to the only known mineral production from the area. In 1900, 15 tons of gold ore, with a reported average grade of 0.29 ounce gold per ton, were milled from the Golden Winner Mine (Wilkinson 1982, p.26). In 1937, a gold-bearing sample of float picked up by a member of a Geological Survey of Canada survey party in the vicinity of Lumby Lake, led to considerable staking activity in the area. Initial staking of the area west of Lumby Lake was done by Red Cedar Lake Gold Mines Limited in 1938. Exploration work consisting of trenching and 4 shallow diamond-drill holes, yielded best assays of 0.18 ounce gold per ton and 7.42% copper over narrow widths in sheared quartz porphyry.

In 1946, C.A. Alcock staked 13 claims on the northeastern shore of Redpaint Lake, about 3 km northwest of the Red Cedar Lake Gold Mines Limited Property. Stripping and trenching revealed numerous small quartz-iron carbonate veins in highly deformed chloritic metavolcanics. Alcock reported assays up to 1.99 ounces gold per ton



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

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for a grab sample and 1.38 ounces gold per ton over 4.5 feet (1.4 m). A grab sample taken by Woolverton (1960, p.47) gave 0.35 ounce gold per ton and 0.48% copper.

In 1948, L.C. Anderson restaked the Lumby Lake (Red Cedar Lake Gold Mines Limited) showing. In 1951, this property was optioned under a joint agreement between Newkirk Company Limited and Noranda Mines Limited. Noranda Mines Limited did geological mapping, trenching, geophysical surveys, and completed 9 shallow diamond-drill holes for a total of 2417 feet. Best assays reported by Noranda Mines Limited (Woolverton 1960, p.46) were 0.034 ounce gold per ton, 0.57 ounce silver per ton, 0.25% copper, 0.22% zinc over 20 feet (6.1 m) in the westernmost trench. Also in 1951, Noranda Mines Limited drilled 10 short diamond-drill holes on 2 quartz veins in the tonalite intrusive complex approximately 3 km west of the Anderson Property. One 6-foot channel sample reportedly contained 4.8 ounces gold per ton, but no significant gold values were encountered in the diamond-drill holes.

In 1954, Balacen Mines Limited held 3 claims at the western end of Lumby Lake. One diamond-drill hole was reportedly drilled to a depth of 500 feet.

Little Long Lac Gold Mines Limited held an option on a group of 32 claims staked in 1950, a few kilometres east of the Anderson Property, on Spoon Lake. Disseminated sulphides in an 8-foot wide zone in sheared quartz porphyry reportedly assayed 0.05 ounce gold per ton, 0.29% copper, 6.74% zinc, 1.75% lead, and a trace of silver for a grab sample from the trench on the northern shore of Spoon Lake (Woolverton 1960, p.48).

In 1970, L.E. Giles staked 20 claims, including part of the original Anderson Property. Oja Limited conducted ground magnetometer and electromagnetic surveys on the Giles and adjacent Univex Mining Corporation Property on Lumby Lake. Seven diamond-drill holes for a total of 1705 feet (520 m) were drilled to test resulting geophysical anomalies.

The Anderson Property was examined yet again in 1975 and 1976 by Kerr-Addison Mines Limited, who conducted magnetometer, VLF, and soil geochemical surveys over an area from Two Bay Lake to Spoon Lake, and drilled 1 shallow diamond-drill hole.

Recent activity commenced in 1979 when P. Sawdo and Mining North Explorations Limited of Atikokan began prospecting in the area between Redpaint Lake and Lumby Lake. By 1980, the property covered the former Alcock and part of the Anderson Properties, and had outlined 7 pit areas of sulphide mineralization. In 1981, W.G. Wahl Limited was contracted to perform magnetometer and VLF surveys, soil geochemical sampling, and geological mapping on the property. In 1982, R. Cote completed geologic mapping and lithogeochemical sampling and recommended further ground electromagnetic surveys in selected areas with possible follow-up diamond drilling.

Steeprock Iron Mines Limited holds 2 small claim blocks in the area near Turning and Theron Lakes.

General Geology

The western half of the Lumby Lake area includes the westernmost portion of the Lumby Lake "greenstone belt" and large areas of granitoid rocks found to the south, west, and north (Figure 1). All bedrock is believed to be Early Precambrian (Archean) in age. The supracrustal rocks of the belt consist dominantly of subaqueously deposited tholeiitic mafic metavolcanics with numerous thin felsic metavolcanic units and relatively rare clastic metasedimentary horizons. The supracrustal rocks are intruded by abundant mafic igneous bodies which also intrude the pre-tectonic Marmion Lake tonalite pluton to the south. Chemical metasediments are rare in the western half of the Lumby Lake area, in contrast to their marked abundance in the eastern half (Jackson 1982).

Felsic metavolcanics occur in at least 2 horizons within the supracrustal sequence. They are best developed in the vicinity of Lumby Lake where a massive, locally mineralized, quartz porphyry unit up to 200 m thick appears to grade to the west into lapilli-tuffs near Two Bay Lake. A second felsic metavolcanic unit, consisting of rhyolitic flow breccia and some pyroclastic rocks, occurs on the southern shores of Bolio and Core Lakes. This unit attains a maximum thickness of 100 m and is poorly exposed over a strike length of up to 2 km.

A centrally located metasedimentary unit about 100 m thick is dominantly composed of coarse-grained arenite and iron-rich carbonate (ankerite), with subordinate amounts of chert, argillite, arkose, conglomerate, and felsic pyroclastic rocks. The metasediments located in the northern part of the area consist of clastic and chemical deposits, which form an east-trending sequence 200 to 300 m thick south of Norway Lake. In the area of Garnet Bay of Norway Lake, the metasedimentary package consists of about 50 m of oxide facies ± silicate facies ironstone interbedded with and overlain by about 50 m of marble, overlain by up to 100 m of conglomerate interbedded with and overlain by 50 to 100 m of garnetiferous wackes. These metasediments are the western extension of the central metasediments in the eastern half of the Lumby Lake area (Jackson 1982).

Two main types of granitoid rocks surround the Lumby Lake "greenstone belt". Earlier, pre-tectonic tonalites and granodiorites occur south and west of the supracrustal rocks. The late, post-tectonic Norway Lake granite pluton occurs north of the "greenstone belt" where it intrudes metasediments and metavolcanics at Norway Lake.

The metamorphic grade of the supracrustal rocks ranges from mid-greenschist to lower amphibolite facies. A prominant amphibolite facies metamorphic aureole is developed up to 2 km from the contact of the post-tectonic Norway Lake granite pluton. No such increase in metamorphic grade is apparent at the southern contact of the "greenstone belt" with the pre-tectonic granitoid rocks. The pre-tectonic Marmion Lake tonalite pluton is extensively intruded by massive and plagioclase-phyric

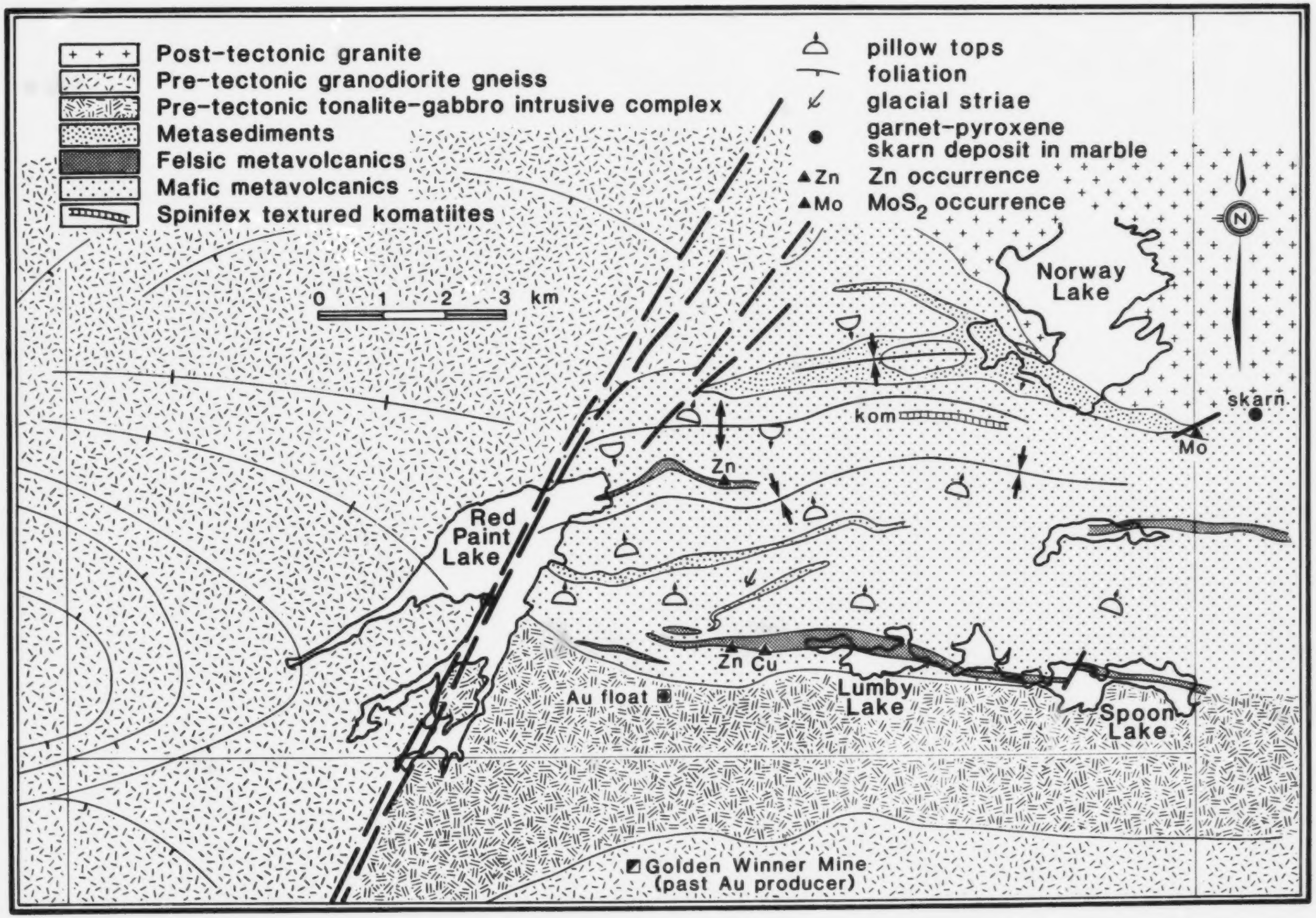
Post-tectonic granite
Pre-tectonic granodiorite gneiss
Pre-tectonic tonalite-gabbro intrusive complex
Metasediments
Felsic metavolcanics
Mafic metavolcanics
Spinifex textured komatiites
pillow tops
foliation
glacial striae
garnet-pyroxene skarn deposit in marble
▲Zn Zn occurrence
▲Mo MoS_2 occurrence
0 1 2 3 km
N
Norway Lake
skarn
Mo
kom
Zn
Red Paint Lake
Zn Cu
Au float
Lumby Lake
Spoon Lake
Golden Winner Mine (past Au producer)

Figure 1. Generalized geology of the Lumby Lake area (western half).

gabbro to diorite sills and dikes. The contact between the supracrustals and the granitoids is obscured by these gabbro and diorite bodies. The author believes that the abundant mafic intrusions within the tonalite complex are contiguous with similar dikes and sills within the metavolcanics, but this is difficult to demonstrate conclusively in the field.

Some significant new findings of the 1983 field season include the discovery of probable skarn mineralization consisting of coarse (>2 cm) garnet + pyroxene(?) crystals in the marble at Spool Lake (Figure 1). Molybdenite was found in 2 locations in late intrusive phases and quartz veins associated with the contact of the Norway Lake granite pluton. Spinifex-textured komatiitic ultramafic flows were found for the first time in the Lumby Lake "greenstone belt" in outcrops approximately 1 km south of Garnet Bay of Norway Lake.

Structure

The structure of the western half of the Lumby Lake area is dominated by the prominent Redpaint Lake fault zone, a regional northeast-trending structure which truncates the "greenstone belt" on the west at Redpaint Lake and juxtaposes it with the gneisses of the Dashwa Lake Batholith (Fenwick 1976, p.26). The fault zone is defined by a broad zone (200 to 500 m) of cataclasis and deformation within both the metavolcanics and gneisses.

Deformation increases outward from the central portion of the "greenstone belt". This is most noticeable in the west and north due to the influence of the Redpaint Lake fault and numerous parallel northeast-trending faults. The main east-trending syncline (S_1), defined by Woolverton (1960), has an axis south of Garnet Bay on Norway Lake. A second east-trending syncline is now inferred from the occurrence of south-facing variolitic pillow lavas at Core Lake (Figure 1). North-trending secondary fold axes (S_2) are inferred from the outcrop pattern of felsic metavolcanic units in northern Hook and Bolio Lakes. The plunge of S_2 crenulation structures at Bolio Lake suggests a steep northward plunge for these folds. Crenulated and contorted schistose mafic metavolcanics on the northeastern shore of Redpaint Lake indicate the presence of similar north-trending S_2 folding, possibly related to drag along the left-lateral(?) Redpaint Lake fault. Lineations of quartz and amphibole in metavolcanics and pre-tectonic tonalite, and minor fold structures in metavolcanics generally plunge steeply to moderately east. In numerous outcrops east of Redpaint Lake, an east-southeast-trending S_1 cleavage cuts north-facing east-trending bedding, suggesting an eastward closing structure.

Economic Geology

Gold

Historically, the Lumby Lake area has been prospected repeatedly for gold and base metals. Two reported occurrences of high-grade gold float from near the western end of Lumby Lake have sparked staking activity around 1940 and 1980. The source of these high-grade boulders has never been discovered. Scattered occurrences of in situ gold mineralization with grades of 1 to 2 ounces gold per ton have also been reported, but never confirmed by subsequent sampling.

The high-grade float occurrence at Bufo Lake was reported to consist of a 30 to 50 cm size boulder of sugary, rusty weathering quartz with 5 to 10%, 2 to 3 mm pyrite cubes. Unfortunately, this boulder has been completely smashed and sampled by numerous geologists since its discovery by P. Sawdo in 1980(?). At the time of my examination, only 0.5 kg or so of broken fragments existed near the discovery site, about 50 m south of Bufo Lake. Evidence of rounding, observed on some larger fragments of this siliceous boulder, suggests that the high-grade float had been glacially transported. It presumably came from a quartz vein or a chemical metasediment source a few, to a few 10s of, kilometres to the north-northeast (025° to 035°) of Bufo Lake.

Preliminary assays of samples collected during the 1983 field season confirm the anomalous gold content of the high-grade float (0.13 ounce gold per ton). Previously reported values ranged from 1.23 to 2.33 ounces gold per ton (AFRO). Available assays of quartz carbonate ± pyrite mineralization in place at the workings of Mining North Exploration Limited at Bufo Lake are generally low in gold content (1 to 55 parts per billion Au), but reported values range up to 0.77 ounce gold per ton (AFRO). There are some indications from reported assays of anomalous gold content (0.03 to 0.05 ounce gold per ton, Woolverton 1960) in the Lumby Lake-Spoon Lake disseminated sulphide zone.

In general, the geologic environment of the western half of the Lumby Lake area appears favourable for gold mineralization because of ubiquitous carbonatization and less common silicification of volcanic and mafic intrusive rocks. Occurrences of iron carbonate (ankerite) with "ladder" quartz veins are common. A massive, stratabound unit iron carbonate is present in the central metasedimentary unit (up to 60 m thick and 2 km(?) long).

Base Metals

There are 2 interesting occurrences of base-metal mineralization in the western half of the Lumby Lake area . The Lumby Lake zone consists of the old Anderson Property at the western end of Lumby Lake, and extends to the recently discovered pit number 1 of Mining North Exploration Limited. An old trench on the Anderson Property north of Morris Lake contains disseminated and stringer pyrite plus chalcopyrite in altered quartz porphyry. Samples from this trench contain up to 1.45% copper over 2 m, and average about 0.4% copper over 10 m (analyzed by the Geoscience Laboratories, Ontario Geological Survey, Toronto). This agrees with assays reported by Woolverton (1960, p.46) averaging 0.6% copper over 50 feet

(15 m). Pit number 1 of Mining North Exploration Limited contains disseminated, fine-grained pyrite, sphalerite, chalcopyrite, and occasional galena in a sericitic, schistose to massive felsic metavolcanic unit, which reportedly contains 0.25% zinc, 0.06% copper, and trace amounts of lead and gold over a 9.6 m channel sample (AFRO). One grab sample from this pit taken by the field party and analyzed by the Geoscience Laboratories, Ontario Geological Survey, Toronto, contained 2.88% zinc and 0.05% copper.

A new zinc occurrence was discovered in 1982 by R. Cote (Mining North Exploration Limited) on the southern shore of Core Lake (Figure 1). Here, a 0.6 m wide siliceous zone, with 5 to 8% sphalerite occurring in stringers, is surrounded by a highly altered chloritoid schist. This zone, which is exposed over a 4 m length, was sampled by the field party and analyzed by the Geoscience Laboratories, Ontario Geological Survey, Toronto, and contained 3.8% zinc over 60 cm.

Sulphide mineralization in quartz arenite also occurs in the central metasedimentary unit. Pyrite clasts and pebbles 5 to 30 mm in diameter make up 5 to 20% of the upper few metres of the 10 to 20 m thick arenite unit. Disseminated pyrite cubes 1 to 2 mm in diameter occur in the overlying ankerite unit. Mining North Exploration Limited pit numbers 3, 6, and 7 are excavated in the arenite unit. Pit number 4 occurs in the ankerite overlying pit number 6. Wilkinson (1982, p.50) reports assays up to 0.03 ounce gold per ton in "pyrite rich tuff" and 0.01 ounce gold per ton in "quartz-carbonate vein" material from the pit number 7 area. At the site of Mining North Exploration Limited pit number 2 on the eastern shore of Two Bay Lake, disseminated to semi-massive sulphide mineralization consisting of 20 to 40%, 2 to 5 mm pyrite cubes with minor chalcopyrite and quartz, occurs in mafic tuffaceous(?) metavolcanics. Grab samples from this pit taken by the field party and analyzed by the Geoscience Laboratories, Ontario Geological Survey, Toronto, contain 0.24 to 0.26% copper and anomalous gold and arsenic values over a 1 m wide zone.

Molybdenum

Small concentrations of molybdenite were found in 2 locations: near the eastern shore of Viking Lake (Figure 1) and about 1 km east of the southern end of Upper Scotch Lake. The mineralization is associated with late intrusive phases and quartz veins found near the contact of the metavolcanics with the Norway Lake granite pluton.

Suggestions to Prospectors

Geologic mapping and lithogeochemical sampling by this field party and previous workers indicates a moderately high potential for the discovery of base-metal (Cu-Zn) mineral deposits of the volcanogenic massive sulphide type in the Lumby Lake area. A large, but low grade, disseminated copper-zinc sulphide zone occurs in felsic metavolcanics in the Lumby Lake-Spoon Lake area. A narrow, but higher grade, zinc sulphide zone occurs in felsic metavolcanics at Core Lake. This zone is hosted by a relatively wide halo of highly altered chloritoid-bearing schist which may be indicative of hydrothermal alteration. The zone outcrops poorly and has not been adequately tested by either geophysical methods or diamond drilling.

The geologic environment of the area appears favourable for the occurrence of gold deposits, but available assays are low and do not confirm previously reported values. The reported association of former producing gold mines (e.g. the Golden Winner Mine) south of the area with northeast-trending shear zones (Wilkinson 1982), suggests that further exploration should concentrate on the Redpaint Lake fault zone and subsidiary lineaments. The Lumby Lake zone also contains reported anomalous concentrations of precious metals, and the possibility of a large tonnage low-grade gold deposit in felsic metavolcanics here should not be overlooked.

The discovery of molybdenite and skarn mineralization (garnet + pyroxene) at the granite contact suggests further exploration for contact metamorphic-type mineral deposits (e.g. W, Mo, Ag) is warranted in this area.

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No. 7 McComber and Vincent Townships, District of Thunder Bay

M.W. Carter[1]

Introduction

The map area comprises the townships of McComber and Vincent in the District of Thunder Bay. It is bounded by Latitudes 49°34′45″N and 49°40′00″N, and Longitudes 87°37′40″W and 87°53′40″W, and is centred approximately 15 km northeast of Beardmore. Highway 11 crosses McComber Township diagonally along its northern part and lies just north of Vincent Township. Logging roads of Domtar Incorporated skirt the map area to the east and south, connecting with Highway 11 to the southwest and northeast of the map area. A branch road off one of these penetrates the southeastern corner of Vincent Township, and a logging road, passable only by 4-wheel drive truck, penetrates southwest McComber Township. This road originates approximately 300 m south of Beardmore. Only 1 lake, Clist Lake at the northeastern boundary of Vincent Township, is accessible by float-equipped, fixed-wing aircraft. Limited access is afforded by the 2 branches of the Blackwater River within the map area owing to its many shallow reaches and rapids. An area of 125 km^2 was mapped during the summer.

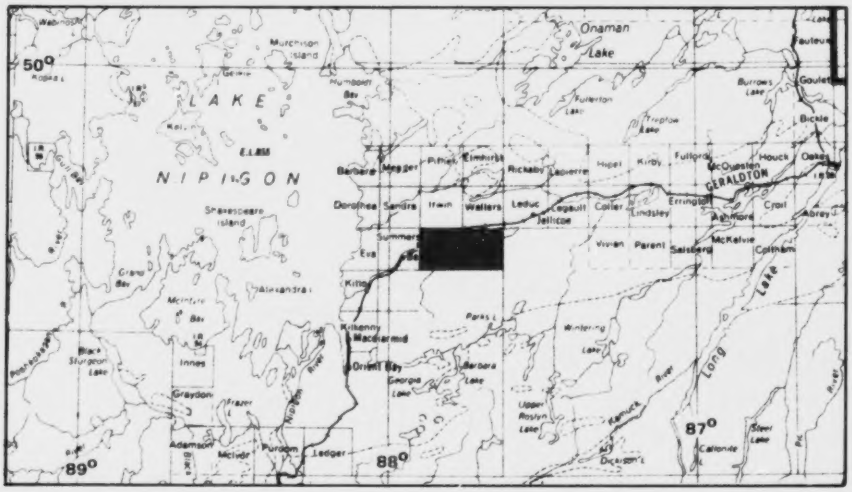
Mineral Exploration

Gold was discovered in the Beardmore-Nezah area in 1916 (Langford 1929, p.102). In 1925, the first claims were staked for gold and by 1927 most of the area was staked. Surface exploration began in 1927 and continued up to the present. Exploration work done in 1927 is described by Langford (1929, p.104-108), and exploration since then is summarized in Table 1 based on material in the Resident Geologist's Files, Ontario Ministry of Natural Resources, Thunder Bay.

General Geology

The map area is underlain by Archean and Proterozoic rocks (Figure 1), mantled by Pleistocene and Recent deposits. The area was previously mapped by Langford (1929) and Peach (1951).

The Archean rocks comprise metavolcanics, metasediments, metagabbroic stocks, granitic rocks, and quartz and/or feldspar porphyries. Diabase dikes, which cut the metavolcanics and metasediments, may be Archean or Proterozoic in age.


50°
LAKE
NIPIGON
Onaman Lake
Murchison Island
Humboldt Bay
Shakespeare Island
Gull Bay
Grand Bay
McIntyre Bay
Black Sturgeon Lake
Fullerton Lake
Burrows Lake
Goulet
Bickle
Barbara
Pifher
Elmhirst
Rickaby
Lapierre
Hipel
Kirby
Fulford
McQuesten
Houck
Oakes
GERALDTON
Dorothea
Sandra
Irwin
Walters
Leduc
Legault
Jellicoe
Colter
Lindsley
Errington
Ashmore
Croll
Abrey
Summers
Eva
Vivian
Parent
Salsberg
McKelvie
Coltham
Kitto
Alexandra
Parks L.
Kilkenny
Macdiarmid
Orient Bay
Wintering Lake
Barbara Lake
Georgia Lake
Innes
Graydon
Frazer L.
Nipigon River
Long Lake
Kenogami River
Upper Roslyn Lake
Adamson
McIvor
Purdom
Ledger
Dickison L.
Steel Lake
Caramat
Pic River
89°
88°
87°

LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

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[1] Geologist, Precambrian Geology Section, Ontario Geological Survey, Toronto.

The metavolcanics comprise mafic flows and minor possibly ultramafic flows and intermediate tuffs. The mafic flows are about 15 to 25 m thick, are dark green to greenish black in colour, and typically consist of a massive medium-grained basal part, a finer grained middle portion, and a fine-grained to aphanitic upper part which is commonly pillowed, amygdaloidal, and/or variolitic. The upper parts of the flows are usually foliated or schistose. The pillows are in most cases deformed, and where least deformed they measure about 0.4 to 0.6 m long by 0.2 to 0.4 m wide. Units believed by the author to be ultramafic flows are fine grained, in one case amygdaloidal, and are about 3 m thick, or are strongly foliated and then only about 1 m thick. The mafic and ultramafic rocks occur in the central parts of the townships and trend northeasterly. Tuffaceous rocks are fine grained to aphanitic, grey or light green, massive, predominantly unfoliated rocks, and are best exposed in the northwestern part of the map area. No lithic fragments or crystals could be observed on the weathered surfaces of these rocks.

The metasedimentary sequence consists of both clastic and chemical metasediments. The clastic metasediments consist predominantly of wackes with minor intercalated siltstone and mudstone. Graded, 8 to 28 cm thick wacke beds consist of a light grey arenaceous lower part and a dark grey pelitic upper part. In many places, these graded beds and other primary structures including flame structures, ball structures, and rip-up structures are well preserved. These rocks form 2 northeasterly trending belts and occur to the northwest and southeast of the mafic metavolcanics. They are homoclinal in both areas; the northern belt is about 3.4 km thick, the southern belt in excess of 5.4 km thick. The metasediments of the southern belt are migmatized in the southeastern corner of the map area.

Chemical metasediments comprise ironstone units 1 to 2 m thick, which consist of alternating bands of almost pure hematite and magnetite, whitish grey recrystallized chert, jasper, and a fibrous radiating iron amphibole reported to be grunerite (Mason and McConnell 1983, p.88). The bands range in thickness from 4 to 10 mm. These ironstone units are interlayered with both the metasediments and mafic metavolcanics.

The mafic metavolcanics are intruded by lensoid, northeasterly trending, medium- to coarse-grained metagabbroic stocks up to 800 m long and 100 m wide. The rocks are predominantly massive but locally show a weak foliation at their contacts or where cut by shear zones. These stocks were intruded before the regional metamorphism and now consist of hornblende and yellowish green altered feldspar.

Felsic intrusive rocks comprise northeasterly trending massive and foliated, white-weathering feldspar and quartz-feldspar porphyry dikes that are 0.5 to 2 m wide and intrusive into both the mafic metavolcanics and metasediments. A grey, massive, medium- to coarse-grained biotite granodiorite to tonalite pluton intrudes the metasedimentary belt in the southeastern part of the map area. The contact area of this pluton is not exposed, but the metasediments in the vicinity of the contact are severely recrystallized. Diabase dikes which are not common in the map area trend north-northeasterly and are from 20 cm to 1.5 m thick. They consist of massive, fine- to medium-grained rocks, and weather to a reddish brown colour. In a few cases, they are porphyritic and

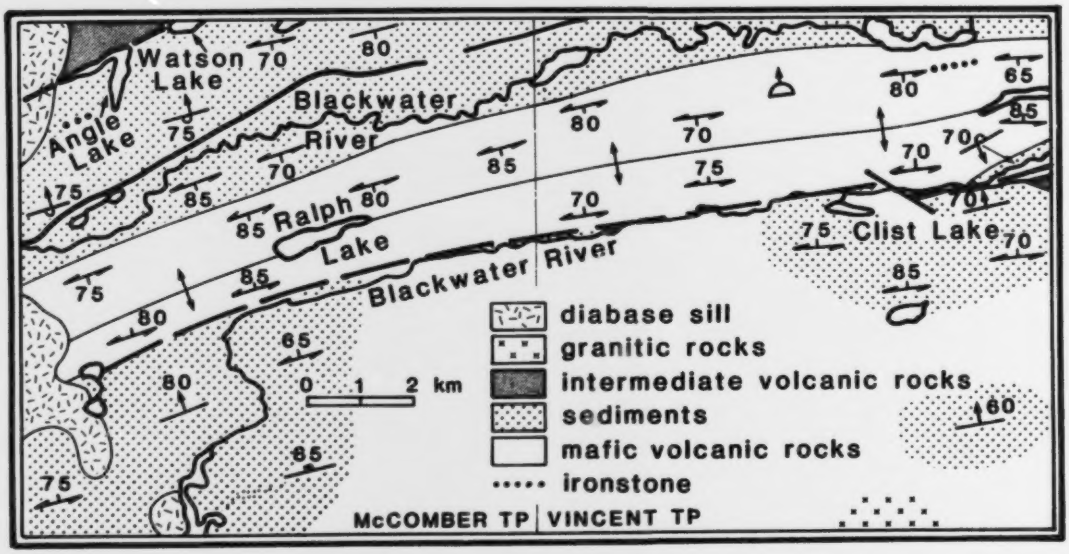

Figure 1. Geological sketch map of McComber and Vincent Townships.

TABLE 1 **EXPLORATION WORK IN McCOMBER AND VINCENT TOWNSHIPS SINCE 1927**

COMPANY OR INDIVIDUAL	DATE OF WORK	WORK DONE	RESULTS OBTAINED
Vega Gold Mines Limited	1937	Trenching	
Dougall Gold Mines Limited	1947-48	34 holes diamond drilled for 2751', and trenching	Best assay: 16.2 ounces gold per ton over 4.0'
Tombill Mines Limited	1952	24 holes diamond drilled for 5156'	Best assay: 0.95 ounce gold per ton over 2.5'
Sogemines Development Company Limited	1958	Geological mapping and geophysical surveying Diamond drilling of unknown amount	Auriferous quartz veins located; magnetic anomalies found Best assay: 0.38 ounce gold per ton over 5'6"
Copper Prince Mines Limited	1958	Geological survey	Jarvela quartz vein traced for 10,000', averaging 1' in width. Best assay 0.38 ounce gold per ton over 12"
W.D. Sutherland	1960	6 holes diamond drilled for	Shear zones located Best assay: 0.035 ounce gold per ton 1441' /over 3.4'
Westfield Minerals Limited	1963	Geophysical (magnetometer and induced polarization) surveys. 3 holes diamond drilled for more than 814'	Only traces of gold obtained from the drillcore
International Nickel Company of Canada Limited	1969	10 holes diamond drilled for 1956'	No assay results given
Hanson Mines Limited	1972-73	6 holes diamond drilled for 508.3'	No assays exceeded 0.02 ounce gold per ton
Tombill Mines Limited	1973	Electromagnetic and soil goechemical surveys	Numerous anomalies found
Tombill Mines Limited	1974	17 holes diamond drilled for 7208'	Best assay: 0.172 ounce gold per ton over 4.4'
N. Maki	1977	1 diamond-drill hole for 102' trenching	No assays given

TABLE 1 EXPLORATION WORK IN McCOMBER AND VINCENT TOWNSHIPS SINCE 1927 (Continued)

COMPANY OR INDIVIDUAL	DATE OF WORK	WORK DONE	RESULTS OBTAINED
B.I. Nelson	1979	Geophysical (magnetometer) survey	Ironstone units were located
E. Harrington	1979-80	Geophysical (magnetometer) survey	100 anomalies located, ranging up to 4025′ long and 150′ wide
	1980	Biogeochemical (humus) survey	2 gold anomalies located
B.I. Nelson	1980	Geophysical (VLF electromagnetic) survey	7 conductive zones located
Hanna Mines Incorporated	1980	Biogeochemical (humus) survey	2 gold and 2 arsenic anomalies located
	1980-81	3 holes diamond drilled for 883′	No assay results were given
Pancontinental Mining (Canada) Limited	1981	Geophysical (electromagnetic, magnetic resistivity) surveys.	Numerous conductors were located
		Geological survey	Linear fissure veins of quartz were located
N. Maki	1982	3 holes diamond drilled for 74′	No assays given
Amax Minerals Exploration	1982	3 holes diamond drilled for 150 m	No assays given
Northwest Geophysics Limited	1982-83	5 holes diamond drilled for about 990′	No assays given
Bema Industries Limited	1983	Survey grid cut	

contain yellow-green phenocrysts of feldspar up to 0.5 cm wide by 1 cm long. They intrude the supracrustal rocks but were not observed to cut the porphyries or granitic rocks.

Proterozoic rocks comprise a diabase sill of medium grain and massive texture, located along the western boundary of the map area. The sill dips about 15° to the west, and occurs as 2 masses: one at the northern, the other near the southern part of the western boundary of the area.

Pleistocene deposits comprise fine, yellow, glaciofluvial sands, well exposed along the northern branch of the Blackwater River, and till exposed in the southeastern corner of Vincent Township (Gartner 1979).

Structural Geology

The supracrustal rocks in the map area have a regional northeasterly trend. The rocks of the northern sedimentary belt are overturned to the south dipping 70° to 80°

southeasterly, and facing northwesterly. They overlie the mafic metavolcanics. Near the central part of the eastern boundary of the area, on the northern shore of Clist Lake, similar metasediments flanking the mafic metavolcanics on the south are overturned to the northwest, face southeast, and dip at 70°. Within the central mafic metavolcanic belt, facing criteria are not common. In the northern part of this belt, the foliation dips steeply southeasterly and in the southern part steeply northwesterly from 70° to 85°. In the northern part of this belt, pillow shapes and upward-fining of grain size in the flows, together with amygdaloidal and variolitic textures, indicate that the flows face north. Ironstone units interlayered with the mafic metavolcanics dip southeasterly in the northern part of this belt and southwesterly in the southern part of the belt parallel to the foliation. On the basis of these observations, the supracrustal rocks are interpreted by the author to be folded about a northeasterly trending anticlinal axis forming a fan-shaped downward-converging anticline (Billings 1972, p.52-53). West of Clist Lake and south of the Blackwater River, the sediments dip steeply, 75° to 80°, to the northwest and are the right way up. This is conformable with the attitude of the mafic metavolcanics to the north of the Blackwater River in this area. This elimination of the southern limb of the anticline is caused by a strike fault trending parallel to the Blackwater River with an interpreted downthrow to the south. Along the southern shore of Clist Lake outside the map area, intermediate tuffaceous metavolcanics overlie the metasediments which are the right way up, and resemble the tuffs in the northwestern corner of the map area. On the basis of all these observations, the supracrustal sequence is interpreted by the author to comprise a lower predominantly mafic metavolcanic unit, overlain by a clastic, predominantly metawacke unit, which is in turn overlain by an intermediate tuffaceous metavolcanic unit, all folded about a northeasterly trending anticlinal axis. The structure can also be interpreted as an overturned anticline.

Economic Geology

Gold was and is the principal metal sought in the map area. Gold mineralization occurs in 3 ways:

1. in quartz and quartz-carbonate veins intruding metavolcanics and metasediments and mineralized with arsenopyrite, pyrite, pyrrhotite, chalcopyrite, and galena, e.g. the Jarvela Vein, the Maki Occurrences. A grab sample taken during the current survey from the Jarvela Vein gave 0.54 ounce gold per ton and 3.02 ounces silver per ton, and grab samples from the Maki veins gave up to 0.81 ounce gold per ton and 5.89 ounces silver per ton (Mason and McConnell 1983, p.89; assays by the Geoscience Laboratories, Ontario Geological Survey, Toronto).
2. in veins in chert-hematite-magnetite-grunerite ironstone units interlayered with the lower metavolcanics and mineralized with arsenopyrite, chalcopyrite, and pyrite. A grab sample from one of these mineralized units taken during the current survey yielded 0.24 ounce gold per ton and 0.14 ounce silver per ton, and from selected grab samples up to 0.40 ounce gold per ton (Mason and McConnell 1983, p.89; assays by the Geoscience Laboratories, Ontario Geological Survey, Toronto).
3. and in pyritized, highly fissile rusty shear zones within the metavolcanics, e.g. the Pichette Occurrence. A grab sample from this occurrence taken during the current survey yielded 0.12 ounce gold per ton and 0.16 ounce silver per ton, and other grab samples assayed up to 0.22 ounce gold per ton (Mason and McConnell 1983, p.89; assays by the Geoscience Laboratories, Ontario Geological Survey, Toronto).

In the present area, ironstones occur on top of volcanic flows and it is in the fine-grained, fissile, upper parts of the flows that quartz vein intrusion and mineralization are concentrated. It is therefore recommended that detailed mapping in the metavolanics be concentrated on tracing out laterally, along strike, the upper parts of flows. Because of this combined structural-lithological-stratigraphic control, mineralized areas could be continuous for large distances along strike. Ironstones overlying are magnetic and could easily be geophysically traced.

Quartz veins have also been found in the metasediments but these are not as numerous. They occupy fractures and shears parallel to the regional dip of the beds. Mineralization comprising galena, chalcopyrite, gold, and silver has been reported (Langford 1929, p.106) but none of these veins was encountered during this survey, though numerous sulphide-free veins were observed. Mineralized veins would be best detected by geochemical surveys as no magnetic minerals are present for detection by magnetometer methods.

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No. 8 Hemlo-Heron Bay Area, Districts of Thunder Bay and Algoma

T.L. Muir[1]

Introduction

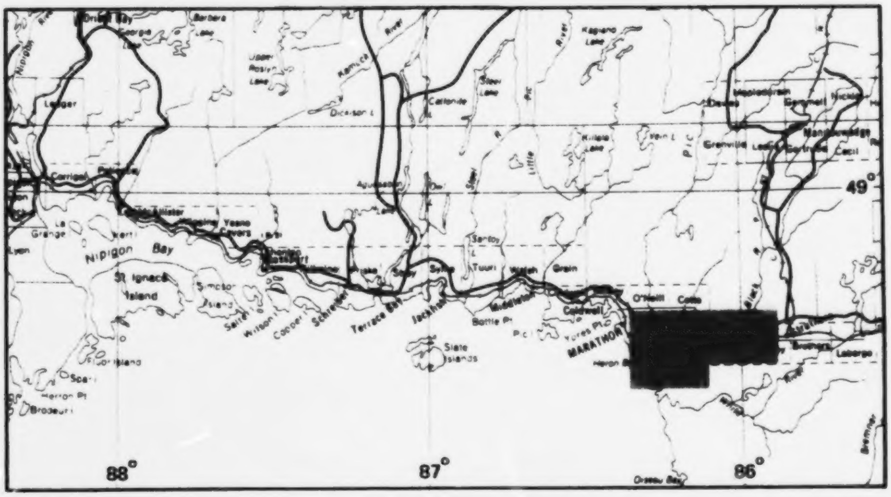
The Hemlo-Heron Bay area, centred approximately 20 km east of Marathon, lies to the west of the intersection of Highways 17 and 614 and straddles the boundary between the Districts of Thunder Bay and Algoma. The area, bounded by Latitudes 48°33′N and 48°45′N, and by Longitudes 85°52′W and 86°23′W, comprises the areas previously described in geological reports on the Heron Bay area (Muir 1982a) and the Hemlo area (Muir 1982b).

The work completed this past field season was preliminary and had 4 main purposes:

1. to outline a detailed mapping project that would cover all the known gold deposits in order to determine both local and regional stratigraphic and structural controls on the mineralization, and to determine the timing of the mineralization event(s). The area to be mapped extends from Rous Lake to Highway 614, along Highway 17 in a zone about 4 km wide.
2. to prepare a detailed highway guide of the roadside outcrops for up-coming field trips of the area
3. to map selected areas of the shoreline of Lake Superior within Pukaskwa National Park in conjunction with Parks Canada
4. to be available for consultation to those mining explorationists working in the area who are interested in the regional geology of the area

Mineral Exploration

Hemlo is well known because of its newly discovered gold deposits currently being developed by Noranda Mines Limited (Golden Giant Mine, on property held by Golden Sceptre Resources Limited and Goliath Gold Mines Limited), Lac Minerals Limited, and Teck Corporation (on property held by International Corona Resources Limited) (Northern Miner Press 1983). All of the ground covering the entire extent of the supracrustal rocks and the adjacent granitoid rocks in the Hemlo-Heron Bay and adjacent areas is solidly staked. Most of the staking was done in a flurry in 1981 and 1982 as a result of reports that significantly more gold mineralization (with minor



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

molybdenite) was present on the property now held by International Corona Resoures Limited (Northern Miner Press 1983) than had been previously outlined up to the mid-1970s (Muir 1982b; Patterson 1983). Further exploration led to the outlining of gold mineralization on the properties of Golden Sceptre Resources Limited, Goliath Gold Mines Limited, and Lac Minerals Limited (Northern Miner Press 1983).

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[1] Geologist, Precambrian Geology Section, Ontario Geological Survey, Toronto.

Geological, geophysical, and geochemical surveys as well as significant diamond drilling were done during the field season on several properties. A description of the assessment work up to 1978 is given in Muir (1982a, 1982b), a summary of the history of the Hemlo deposits is given in Patterson (1983), and a collection of newspaper articles on events at Hemlo printed in the Northern Miner can be found in a booklet by Northern Miner Press (1983).

General Geology

The area is underlain by metavolcanics and metasediments of 2 groups (Playter Harbour; Heron Bay), by 4 major granitoid bodies (Pukaskwa Gnessic Complex; Gowan Lake Pluton; Heron Bay Pluton; Cedar Lake Pluton), and by minor mafic, ultramafic, and felsic intrusions (Figure 1). The geology has previously been describd by Thomson (1931), Bartley and Page (1958), and Muir (1982a, 1982b). A modified summary of the general geology of the Hemlo-Heron Bay area, based on previous work, was prepared by Muir (1983). More detailed mapping by geologists from mineral exploration companies, by G.C. Patterson (Resident Geologist, Ontario Ministry of Natural Resources, Thunder Bay), and by the author has resulted in changes in the published geological interpretations.

Detailed mapping of the area east of the Hemlo-Heron Bay area was undertaken this field season at a scale of 1:15 840 by G.M. Siragusa (Geologist, Precambrian Geology Section, Ontario Geological Survey, Toronto; *see* Siragusa, this volume).

The presently defined gold deposits in the Hemlo-Heron Bay area are underlain by intermediate and lesser felsic calc-alkalic pyroclastic rocks (lapilli-tuff, tuff, tuff-breccia), tholeiitic mafic flows (pillowed, variolitic), and metasediments (sandstone, siltstone, conglomerate, magnetite ironstone). The chemical composition of many of the clastic metasediments suggests they were derived largely from volcanic deposits (possibly unconsolidated) and their sedimentary structures show that they are submarine fan deposits; most are typical of the lower parts of a fan.

The aforementioned rocks have been intruded by feldspar porphyry dikes, sills, and plugs of varied texture and composition, as well as by sub-alkalic diabase dikes and rare pyroxenitic(?) sills, and biotite and pyroxene-magnetite lamprophyre dikes.

The gold and molybdenite mineralization of the Hemlo deposits, where exposed beside the highway on the property of International Corona Resources Limited, is associated with a rock which may be either: a) a bedded felsic lapilli-tuff, or reworked tuff or sediment, with at least 3 types of mineralogically different fragments (quartzofeldspathic, quartz, green mica); or b) a mylonitized (used in the sense of reduced grain size with accompanying overall extension of fragments and matrix) rock having a similar lithologic origin or some other origin.

Structural Geology

Examinations of highway exposures indicate that these rocks are moderately to strongly deformed, particularly within the vicinity of the gold deposits. Tight isoclinal folds, some of which are overturned, shearing, and mylonitization (used in the sense of reduced grain size with accompanying overall extension of fragments and matrix) have all been identified in more than one location. What is not known at this time is the overall scale of the structures and the ultimate effect or control that deformation has had on the mineralized zones and their extensions. These effects would partly depend on the relative timing of the mineralization and the deformation, which at present appears to be the subject of debate.

Economic Geology

The chief interest at this time is in the potential for gold mineralization in the Hemlo-Heron Bay area and its surrounding areas. Economic gold deposits have been outlined near Hemlo totalling 51.7 million tons grading 0.23 ounce gold per ton (Northern Miner, October 13, 1983) and the full extent of these deposits is not known.

A previously outlined molybdenum deposit (*see* R.A. Schiralli Deposit; Muir 1982a) within the Playter Harbour Group, on the property currently held by Maple Leaf Petroleum Limited, south-southeast of Heron Bay, was re-investigated this season.

The potential for gold and associated minerals in the Hemlo-Heron Bay area is far from being fully assessed.

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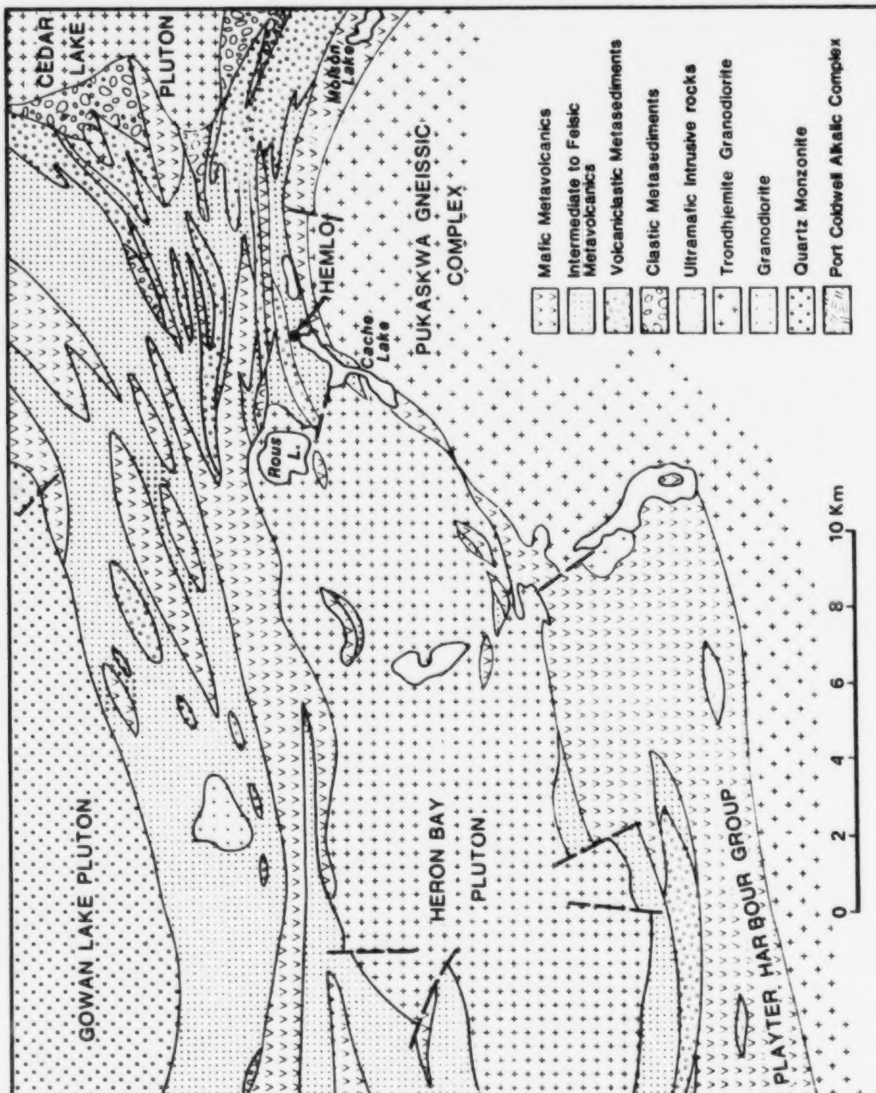
PORT COLDWELL ALKALIC COMPLEX
GOWAN LAKE PLUTON
CEDAR LAKE PLUTON
HERON BAY GROUP
HERON BAY
HERON BAY PLUTON
PLAYTER HARBOUR GROUP
PUKASKWA GNEISSIC COMPLEX
HEMLO
Molson Lake
Cache Lake
Rous L.
Heron Bay
Pulpwood Harbour
Playter Harbour
Lake Superior
N
0
2
4
6
8
10 Km
Mafic Metavolcanics
Intermediate to Felsic Metavolcanics
Volcaniclastic Metasediments
Clastic Metasediments
Ultramafic Intrusive rocks
Trondhjemite Granodiorite
Granodiorite
Quartz Monzonite
Port Coldwell Alkalic Complex

Figure 1. Geology of the Hemlo-Heron Bay area.

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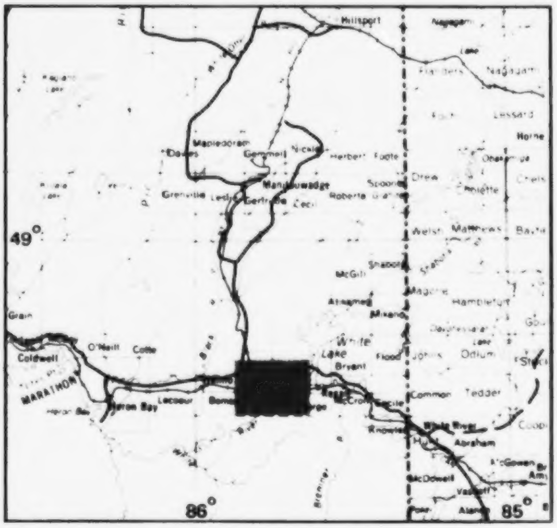
No. 9 White Lake Area, District of Thunder Bay

G.M. Siragusa[1]

Introduction

The area mapped in the summer of 1983 is bounded by Latitudes 48°38'N and 48°45'N, and by Longitudes 85°38'W and 85°52'30''W. This area adjoins the Hemlo area (Muir 1982) to the east and includes most of Laberge and Brothers Townships, part of Bomby Township, and a northern strip of unsurveyed land totalling 252 km^2. The Trans-Canada Highway (Highway 17) and the Canadian Pacific Railway cross the central part of the area. The distance between the map area and Sault Ste. Marie, via Highway 17, is approximately 412 km.

White Lake and segments of White River offer convenient access by canoe to eastern, southeastern, and south-central parts of the area. Cedar Lake and the segment of Cedar Creek south of Highway 17 provide access to southwestern parts of the map area. White Lake and Cedar Lake are reached directly from Highway 17. Under favourable wind conditions, the east-trending segment of the White River, downstream of the third set of rapids in southern Brothers Township, can be used as an access point by bush plane. Fixed-wing aviation service is available in Manitouwadge. Highway 614, the Manitouwadge road, provides access to the northwestern margin of the area. North-central parts of the area can be reached from the southern tip of Wabikoba Lake (north of map area) which is accessible from Highway 614 by a gravel road about 10 km long. Access to the northeastern part of the map area is either by bush traverses, utilizing Highway 17 as a "base line", or by helicopter. Throughout the summer of 1983, helicopter service was available on Highway 17 at Dunc Lake, about 5 km west of White Lake Narrows. The map area includes the White Lake Provincial Park, which covers about 15 km^2 of sandy terrain located south of Highway 17 between the western shore of White Lake and the eastern shore of Dunc Lake.


Hillsport
Nagagami
Flanders
Nagagami
Lessard
Horne
Maplecoram
Dawes
Gemmell
Nicol
Herbert
Foote
Drew
Manitouwadge
Grenville
Gertrude
Cecil
Roberta
Spooner
49°
Welsh
Matthews
McGill
Shabotik
Magone
Hambleton
Grain
Mikano
Coldwell
O'Neill
Cotte
White
Lake
Bryant
Flood
Odlum
MARATHON
Heron Bay
Lecours
Common
Tedder
White River
Abraham
McDowell
86°
85°

LOCATION MAP

Scale: 1:1 584 000
or 1 inch to 25 miles

Mineral Exploration

In the past, little exploration was carried out in the area. In 1968, 7 diamond-drill holes totalling 3586 feet were completed by Mattagami Lake Mines Limited in an area of southeastern Brothers Township. In 1975, airborne and ground geophysical surveys were conducted by the same company on a property consisting of 8 contiguous claims located in southwestern Laberge Township, and in 1977, 2 diamond-drill holes totalling 502 feet were completed in this area.

At the time of writing, most of the map area is covered by interlocking claim groups owned by some 33 different companies or persons (*see* property map accompanying the Canadian Mines Handbook 1983-84). Lac Minerals Limited owns the largest property, which extends beyond the western and eastern boundaries of the present map area, and as of September 13, 1983, consisted of a block of 659 unpatented claims (I. Hamilton, Vice-President, Lac Minerals Limited, Toronto, personal communication, 1983).

During the summer of 1983, exploration activity, consisting of line cutting, geological mapping, geophysical surveying, soil sampling, stripping, blasting, trenching, channel sampling, and diamond drilling, was carried out in parts of the area.

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General Geology

The southern half of the map area is underlain by Archean supracrustal rocks which trend east and southeast, dip north at generally steep angles, and are hereafter referred to as the "Main Belt". Northeastern parts of the map area are underlain by Archean metasediments which trend southeast, dip subvertically or steeply southwest, and are hereafter referred to as the "Northern Belt". A large central portion of the map area is underlain by granitic rocks that are younger than the regional granitic rocks, and are part of the Cedar Lake Pluton (Muir 1982).

The segment of the Northern Belt within the map area is 9 km long, and has minimum and maximum widths of 1.6 km and 4 km. This belt extends considerably north of the map area, forms a complex loop around the Cedar Lake Pluton, and eventually joins the Main Belt west of the map area (Thomson 1932, Map 41j).

The segment of the Main Belt within the map area is about 20 km long, has minimum and maximum widths of 3.2 km and 5.7 km, and consists dominantly of metasediments with lesser metavolcanics. The metasediments in the northern section of this belt are along strike of the gold deposits presently being developed 2.5 km west of the map area (*see*Muir, this volume).

The portion of the Cedar Lake Pluton within the map area is a wedge-shaped southeast-trending body which narrows consistently to the southeast; this suggests that the Main Belt and the Northern Belt join east of the map area (i.e. about 4.4 km southeast of Mobert). If these belts do not join now, then they most likely did during early stages of emplacement of the pluton. This is consistent with the presence of steeply southeast-plunging subsidiary folds in metasediments of the Northern Belt close to the western shore of White Lake. The Cedar Lake Pluton is therefore enveloped by deformed supracrustal rocks; this is probably the most important single feature in relation to structure and stratigraphy of the map area.

Main Belt

The dominant metasediments are medium-bedded to laminated equigranular meta-arenites which commonly are almost entirely quartzofeldspathic except for minor biotite. The meta-arenite is locally interbedded with wacke, cherty units, and calcsilicate rocks. Meta-arenite of high (regional or contact) metamorphic rank is a grey rock which fractures into splinters. It is locally retrograded to fissile quartz-muscovite schist which is white to reddish in colour, depending on the amount and degree of oxidation of the pyrite. The metamorphic derivatives of wacke include relatively hard greyish-mauve rocks heavily textured by linear arrays of garnet metacrysts, and rocks with higher pelitic content that were metamorphosed to brown biotite-rich schists, soft enough to be crumbled by hand. Calcsilicate rocks of relatively high grade metamorphism exhibit alternating white and grass-green laminae, and contain scattered garnet metacrysts up to 20 mm in size. They consist dominantly of (green) diopside and subordinate grossularite-rich garnet, calcite, and tremolite (X-ray diffraction determinations by W.D. Hicks, Mineralogist, Geoscience Laboratories, Ontario Geological Survey, Toronto). A thin molybdenite-bearing unit of this type occurs approximately 300 m northeast of Molson Lake. Calcsilicate rocks of lower metamorphic grade consist of medium-grained, green or dark green amphibolite, which commonly occurs as strongly deformed lenses within other metasediments.

A characteristic feature of the area is that, even units that are relatively thin, are generally traceable over significant distances along strike. In general, the metasediments in the western half of the belt were deposited in a relatively distal environment which was probably reducing, as suggested by pyrite traces commonly found in these rocks.

The metavolcanics include tholeiitic basaltic flows and coarse pyroclastic rocks of varied composition. Aphanitic rocks of dacitic composition are comparatively minor, and are associated with cherty units which occur locally in the metasediments. Metamorphosed basaltic flows form the southernmost part of the belt, and include a relatively thin variolitic unit, which thickens eastward, and extends the whole length of the belt. Apart from this feature, metabasalt consists of texturally and compositionally uniform fine- or medium-grained amphibolite which very rarely shows primary structures. A relatively large unit of metabasalt is also found interbedded with metasediments in northwestern parts of the belt. In the western half of the belt, distal metasediments and metabasalts account, respectively, for 75 and 25% of the belt's thickness.

In (rare) good exposures, the pyroclastic rocks exhibit fine-grained lenticular felsic clasts, up to a few decimetres in length, set in a mafic matrix (e.g. White River Dam). More commonly, however, these rocks consist of variegated schists which contain significant volumes of chlorite (retrograde) or hornblende, and probably have an overall intermediate composition. The variables that affect the appearance of these rocks, to a large extent, are the frequency and distribution of clasts across and along foliation, and the degree of shortening normal to foliation. These rocks are the major lithology in the eastern half of the belt, and close to the eastern boundary of the map area, they account for most of the belt's thickness. This, and the eastward thickening of the variolitic unit, suggests that the easternmost segment of the belt is a relict volcanic centre. The pyroclastic rocks are locally associated with proximal metasediments (pebbly meta-arenite), and were probably important source rocks for the metasedimentary assemblage in the western half of the belt. The basalts were likely to have been lesser contributors to this metasedimentary assemblage. Apart from the comparatively wacke-rich character of the assemblage in proximity to the tholeiites, the overall composition of the metasediments is generally too felsic to suggest that basalt was a significant source rock.

The supracrustal rocks are intruded by numerous syntectonic (or pretectonic) felsic dikes, which include porphyritic and equigranular granitic and aplitic rock types. The porphyritic texture of some of these dikes is the result of shearing. The deformation undergone by these dikes varies from the development of a mild foliation, to ultraboudinage, to nearly complete obliteration.

A broadly concordant elongate body of syenite porphyry was found south of White River in southeastern Brothers Township. This body trends east-southeast, is 3.2 km long, and has minimum and maximum widths of 200 m and 550 m. It is essentially undeformed and is associated with, but apparently not affected by, a southeast-trending dextral fault which offsets the southern margin of the belt by about 900 m.

Diabase dikes, trending northwest to northeast, cut the granitic and supracrustal rocks; rare lamprophyre dikes also cut the latter.

Northern Belt

This belt consists of relatively poorly exposed metasediments which are similar to those of the Main Belt in that meta-arenite appears to be dominant. The belt is bounded to the south by the Cedar Lake Pluton, and to the north by regional granitic rocks. The northern contact zone is poorly defined and migmatitic in character. No volcanic units of significant size occur in this belt. Small lens-like units of metabasalt and coarse epiclastic rocks are locally interbedded with meta-arenite adjacent to the migmatitic zone. The belt extends considerably beyond the map area. The segment of the belt within the map area is too short to justify suggestions as to the source area of the metasediments.

Metamorphism

The supracrustal rocks are affected by: a) regional metamorphism which is dominantly of amphibolite rank, b) contact metamorphism which is associated with the intrusion of the Cedar Lake Pluton, and c) local contact and/or retrograde metamorphism associated with emplacement of syntectonic felsic dikes. There is little doubt that the cumulative thickness of the syntectonic felsic dikes constitutes an appreciable fraction of the Main Belt. They occur at all stratigraphic levels, and are believed to be related to progressive stages of emplacement of the Cedar Lake Pluton. The intrusion of some of these dikes has caused local recrystallization of their host rocks and retrograde shearing of adjacent units.

At the present scale of mapping, the components of regional and contact metamorphism cannot be adequately assessed. For instance, the calcsilicate mineralogy of rocks northeast of Molson Lake (discussed under "Main Belt") could have resulted from regional metamorphism of almandine-amphibolite facies, or contact metamorphism of hornblende-hornfels facies. The second possibility is favoured by the writer despite the fact that the contact aureole of the Cedar Lake Pluton is poorly defined. One of the characteristic features of this aureole is the widespread (and locally spectacular) development of silicification along fractures and joints in the supracrustal rocks, particularly in the metasediments. Hematitization and epidotization are also locally conspicuous.

Structural Geology

Salient points to be considered in the discussion of the structural configuration of the map area are:

1. Bedding planes of the Main Belt are generally east trending and dip consistently to the north.
2. In the Northern Belt, bedding planes trend southeast and dip either subvertically or steeply to the southwest.

These conditions clearly indicate that the Main Belt and the Northern Belt are downward-converging structures.

Supracrustal lensoid xenoliths occur in massive granodiorites of the Cedar Lake Pluton. These xenoliths define a planar fabric which trends east, dips consistently to the north parallel to bedding in the Main Belt, and hence suggests that the Main Belt dips beneath the (younger) Cedar Lake Pluton.

In eastern parts of the map area, the basalt along the southern margin of the Main Belt has been intruded by regional granitic rocks, which are therefore younger. In western and central parts of the map area, however, these granitic rocks have been affected by dynamometamorphism, and the resulting gneisses dip beneath the basalt at angles of 40° to 80° north. These relationships may imply that the Main Belt is overturned.

The general setting of the Cedar Lake Pluton (discussed under "General Geology") suggests a diapiric mode of emplacement in the central portion of an overlying supracrustal cover. It would also appear that the present erosional surface has exposed a relatively deep level of the pluton, that is, the "stem" beneath the bulge of the diapir. This deep level of erosion is reflected in the overall high metamorphic grade of the adjacent supracrustal rocks, and their downward-converging structural attitude. If the Main Belt (as a whole) is overturned, then not necessarily all of its component units are south-facing; this depends on the type and extent of folding (within the belt). Small, tight, isoclinal folds were noted at a few localities. While these folds differ from one another with respect to magnitude and direction of plunge of their axes, their axial plane is invariably normal to the general north-south direction of regional shortening. Although their presence could theoretically be related to large-scale isoclinal folding, this is regarded as unrealistic because of the markedly asymmetrical distribution of metavolcanics and metasediments between the northern and southern sections of the Main Belt. It is suggested, therefore, that the Main Belt might represent an essentially monoclinal structure which is overturned and south-facing.

The largest volume of basalt occurs in the southernmost section of the Main Belt and hence, if the belt is overturned, the bulk of the sediments to the north (of this section) must have originated from sources other than basalt.

Economic Geology

The drill logs of Mattagami Lake Mines Limited (discussed under "Mineral Exploration") show values of 0.2 to 0.6% zinc over core lengths of up to about 50 feet. The log of 1 hole (company hole number C.O.-68-2) shows 1.7% zinc in a 5-foot section logged as andesitic tuff, and the same zinc values in another 5-foot section logged as red porphyritic dacite. The log of another hole (C.O.-68-7) shows 1.7% zinc in a 5-foot section logged as porphyritic rhyolite, and 2.4% zinc in another 2-foot section logged as altered rhyolite. The logs of some of the holes show gold assays which vary from 0 to trace (White Lake, Drilling Report #10, Assessment Files Research Office, Ontario Geological Survey, Toronto).

The northern section of the Main Belt is a prime target for gold exploration because it is directly along strike of the Hemlo gold deposits (Muir, this volume), and is adjacent to the Cedar Lake Pluton.

During present mapping, a total of 235 grab samples were collected from gossan zones, various kinds of schists, cherty units, porphyries, and quartz veins. These samples were assayed for gold by the Geoscience Laboratories, Ontario Geological Survey, Toronto. The results are as follows: 175 samples assayed 2 parts per billion (ppb) gold or, more commonly, less. Out of the remaining 60 samples, 53 samples have gold contents which are mostly between 3 and 8 ppb, and are up to 10 to 16 ppb in a few samples. The remaining 7 samples assayed comparatively high gold values. Of these samples, 3 contain 80, 260, and 750 ppb gold. These were from strongly altered xenoliths of metavolcanics and metasediments which are a few metres thick, and occur within massive granodiorite of the Cedar Lake Pluton. These xenoliths are situated close to the western boundary of the map area, in the contact zone of the pluton with the Main Belt. One of the remaining 7 samples assayed 120 ppb gold; this sample is from a garnetiferous unit within metasediments close to the main south-pointing meander of Cedar Creek. This unit parallels the southern margin of the Cedar Lake Pluton, and is believed to lie within its contact aureole. The last 3 samples are from molybdenite-bearing granitic dikes which are up to a few decimetres thick, contain acicular aggregates of tremolite/actinolite, and cut a (presumably) small basaltic unit in the Northern Belt. This unit is in the northern contact zone of the Cedar Lake Pluton slightly east of the map area. The assays of the 3 samples are as follows:

Mo (ppm)	Au (ppb)
440	170
2570	110
725	670

A second area where prospecting might be justified is the contact zone of granitic and basaltic rocks on the southern side of the Main Belt. In the central and western parts of the map area contact relationships are very sharp, and shearing associated with overturning may have resulted in least-resistence paths for mineralizing fluids.

Another geological setting which could be of interest is that offered by the syenite porphyry (discussed under "Main Belt"); the size, late age, and association with faulting of this body seem to suggest conditions which could have merits of their own.

References

Muir, T.L.
1982: Geology of the Hemlo Area, District of Thunder Bay; Ontario Geological Survey, Report 217, 65p. Accompanied by Map 2452, scale 1:31 680 or 1 inch to ½ mile.

Thomson, J.E.
1932: Geology of the Heron Bay-White Lake Area, District of Thunder Bay; Ontario Department of Mines, Annual Report for 1932, Volume 41, Part 6. Accompanied by Map 41j, scale 1:126 720 or 1 inch to 2 miles.

No. 10 Josephine Area, District of Algoma

R.P. Sage[1]

Introduction

As part of the continuing long-range mapping program of the Wawa area (Sage 1979, 1980, 1981, 1982; Figure 1) portions of 4 townships were mapped during 1983. Access to those areas mapped was by float-equipped aircraft, Algoma Central Railroad right-of-ways, and 4-wheel drive vehicle.

Mineral Exploration

Aguonie Township

Mapping in 1963 was restricted to the central and southern parts of the township. The areas examined are not known to contain mineralization of economic interest, although several occurrences of pyrite were located this past field season by the field party. Several quartz veins found by the field party had already been sampled by persons unknown. A lead showing is reported to occur in the central portion of the township, but its precise location is unknown and was not found by the field party (Assessment Files Research Office, Ontario Geological Survey, Toronto (AFRO)). The township is currently being examined by Manwa Exploration Services Limited.

Abotossaway Township

The Kozak gold-silver Occurrence is located within the area examined. This occurrence has been extensively investigated since its discovery in 1927. It consists of narrow quartz veins and fracture fillings accompanied by galena, sphalerite, pyrite, and chalcopyrite in highly carbonatized and schistose intermediate to felsic metavolcanics.

The property has had 3 diamond drill programs totalling approximately 7237 m (AFRO). A shaft 36.6 m deep, and 102.0 m of lateral work has been completed (AFRO). Recent work on the property by Golden Spoke Mines Limited has outlined 5 mineralized zones containing gold and silver (AFRO).

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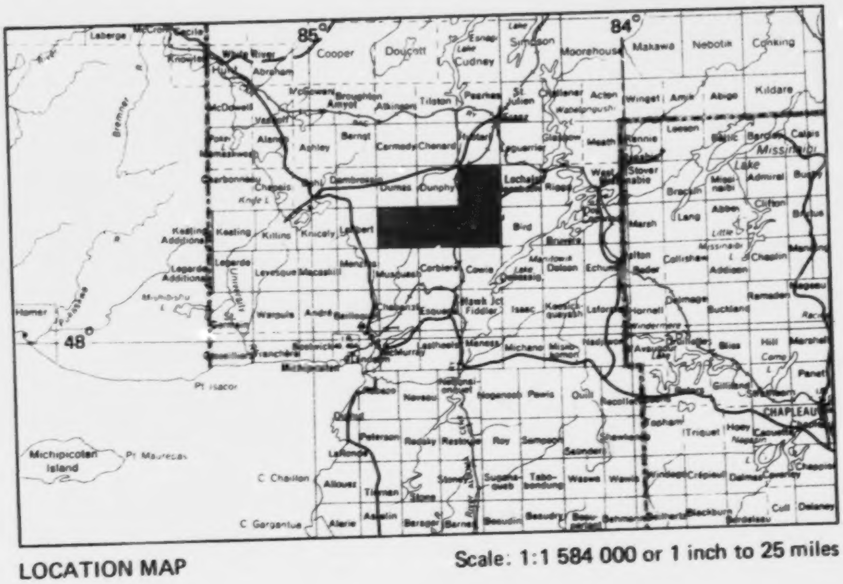
[1] Geologist, Precambrian Geology Section, Ontario Geological Survey, Toronto.



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

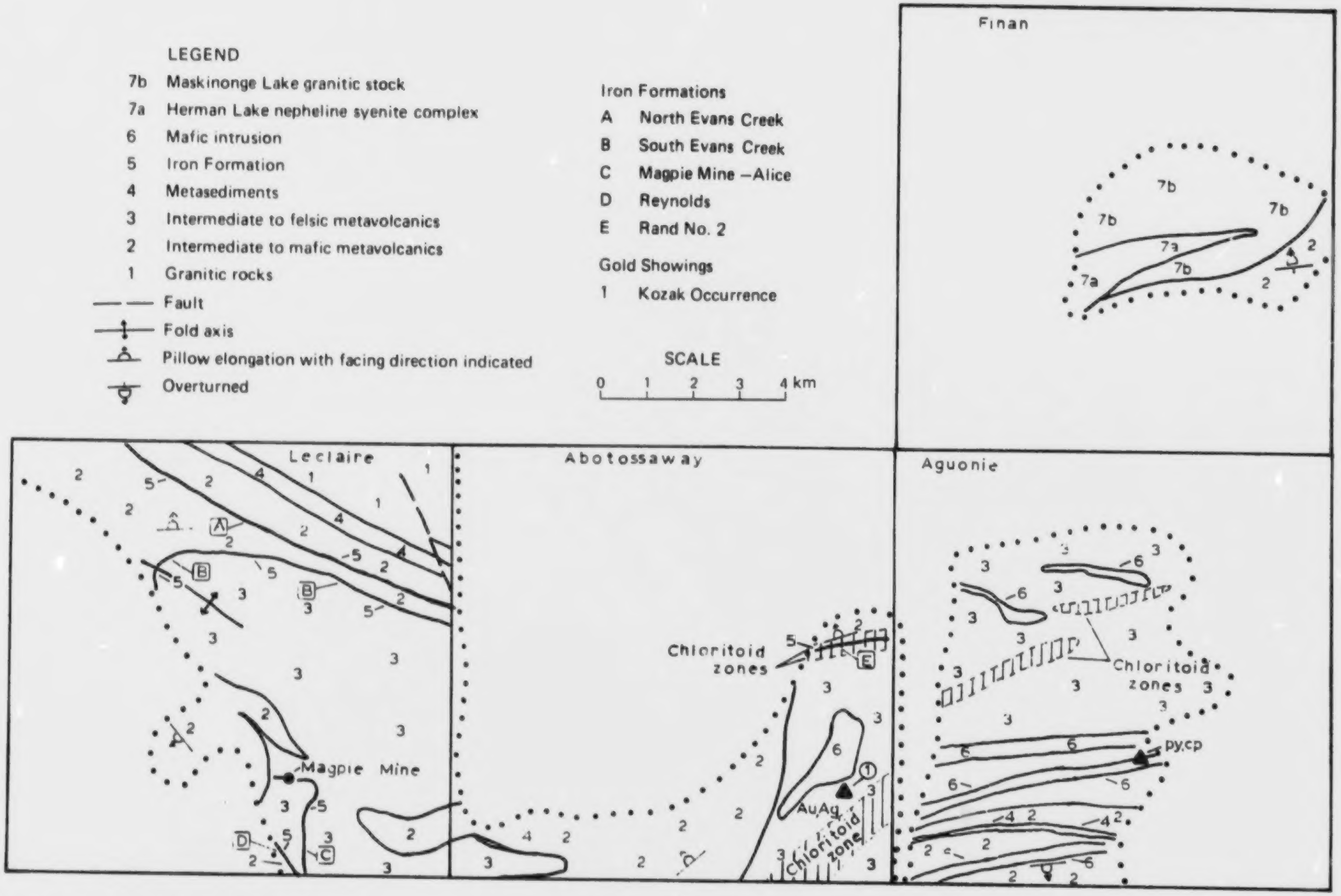

LEGEND
7b Maskinonge Lake granitic stock
7a Herman Lake nepheline syenite complex
6 Mafic intrusion
5 Iron Formation
4 Metasediments
3 Intermediate to felsic metavolcanics
2 Intermediate to mafic metavolcanics
1 Granitic rocks
Fault
Fold axis
Pillow elongation with facing direction indicated
Overturned
Iron Formations
A North Evans Creek
B South Evans Creek
C Magpie Mine – Alice
D Reynolds
E Rand No. 2
Gold Showings
1 Kozak Occurrence
SCALE
0 1 2 3 4 km
Finan
Leclaire
Abotossaway
Aguonie
Magpie Mine
Chloritoid zones
Chloritoid zone
Chloritoid zones
AuAg
py,cp

Figure 1. Schematic diagram illustrating the geology of Leclaire, Abotossaway, Aguonie, and Finan Townships.

The Rand No. 2 iron formation located in the northern portion of the area mapped is a typical Michipicoten-type iron formation in which the sulphide facies is well developed. From bottom to top, the iron formation consists of siderite, pyrite, and thinly bedded chert-wacke. The unit separates intermediate to felsic volcanic breccias at the bottom, from pillowed and massive intermediate to mafic pillowed lavas above. Pervasive carbonate alteration, commonly displaying well developed chloritoid crystals, is present above and below the iron formation.

The iron formation has undergone extensive testing as a source of pyrite for the production of sulphuric acid. The sulphide horizon is of varied thickness and locally exceeds 30 m in width. The iron formation has been explored over a strike length of approximately 1.6 km. The Rand No. 2 iron formation ranges in width from 16 to 53 m and is broken into several segments by faulting.

Since 1915 the property has been explored 3 times by diamond drill programs totalling approximately 10 277 m, and 2 adits have been driven into the iron formation (AFRO). The most recent work by Superior Acid and Iron Limited (1925?) indicated reserves estimated at 13 600 000 tons grading 24.0 to 25.1% sulphur.

Portions of the township are currently being explored by Manwa Exploration Services Limited.

Finan Township

In 1983 mapping was completed on the plutonic rocks of the Herman Lake nepheline syenite stock and on the Maskinonge Lake granitic stock. No evidence of former prospecting activity was encountered, nor is there any record of mineral occurrences in the area investigated. The area is now completely covered by recent staking.

Leclaire Township

Mapping was concentrated in the northeastern and southeastern portions of the township. In the northeastern portion of the township the Evans Creek iron formation consisting of chert-magnetite-wacke was tested by diamond drilling for its iron content by Algoma Ore Properties Limited in 1953. A total of 1147 m of diamond drilling was completed.

In the southeastern corner of the township mapping was begun in proximity to the former Magpie Iron Mine. This mine closed in 1922 after producing 1.5 million tons of siderite (AFRO). Reserves of 0.75 million tons of siderite remain within the mine. The siderite deposit was developed by a 203.6 m vertical shaft and considerable lateral work (AFRO). In 1909 to 1910, 17 surface diamond-drill holes were completed by the Lake Superior Corporation Limited, and in 1952, 4 diamond-drill holes totalling 1837 m were completed by Algoma Ore Properties Limited (AFRO).

The Alice iron range occurs southeast of the Magpie Mine and was subjected to extensive trenching and diamond drilling in 1910 by the Lake Superior Corporation Limited. A total of 1621 m of drilling has been completed on this range (AFRO).

The township has been subjected to airborne geophysical surveys and follow-up work by Acme Gas and Oil Limited, Umex Incorporated, Noranda Exploration Company Limited, and Amax Exploration Incorporated (AFRO). The township is currently being examined by Manwa Exploration Services Limited.

The rocks within the area of the mine appear to be pervasively 'soaked' with silica. While very localized silicification has been observed in the Wawa mapping program, this is the first observation of widespread silicification over a broad area and represents a new-found style of alteration in the Wawa area.

General Geology

Aguonie Township

In central Aguonie Township the rocks consist of intermediate to felsic breccias, lapilli tuffs, tuffs, feldspar crystal tuffs, and massive flows. These rocks are commonly schistose, often fissile, and moderately to heavily carbonatized. Several areas of chloritoid development were delineated. The extrusive rocks have been intruded by massive medium-grained diorite to quartz diorite bodies.

Along the southern margin of the township, abundant outcrop delineates intermediate to felsic metavolcanics to the north and pillowed to massive intermediate to mafic metavolcanics to the south. Both mafic and felsic metavolcanics have been intruded by gabbro to quartz diorite intrusions.
A minor band of siltstone, wacke, and conglomerate extends across the southern margin of the township.

Abotossaway Township

The rocks in the southeastern corner of this township consist dominantly of intermediate to felsic metavolcanics of the Alden Lake Volcanic Centre. The metavolcanics consist of breccias, lapilli tuffs, tuffs, flow banded flows, and feldspar crystal tuffs. The rocks have been pervasively impregnated with carbonate and are commonly highly schistose. A zone of chloritoid alteration approximately 700 m thick is present in this section. Minor chloritoid is present at the Kozak gold-silver Occurrence but there is no clear relationship between its presence and mineralization.

The metavolcanics have been intruded by large masses of fine- to medium-grained quartz diorite.

Intermediate to mafic pillowed to massive metavolcanics occur above the Rand No. 2 iron formation.

Finan Township

The nepheline syenites of the Herman Lake nepheline syenite stock are medium to coarse grained and are estimated to contain up to 40% nepheline, now commonly altered to a pale orange cancrinite. Along the margins of the stock a relatively narrow band of fine- to medium-grained mafic rock consisting of amphibole and nepheline has been partially delineated. The Maskinonge Lake granitic stock is medium grained, massive, and intrudes the Herman Lake nepheline syenite stock. The granitic stock is locally quartz deficient and grades into an amphibole syenite. Amphibole syenite is also present as a reaction zone separating nepheline syenite xenoliths from the more quartz-rich rocks of the stock. Rare purple fluorite occurs along fractures in the granitic stock.

Minor amounts of pillowed to massive intermediate to mafic metavolcanics occur in the eastern portion of the area mapped.

Leclaire Township

The northeastern portion of the township is underlain by sparse outcroppings of boulder conglomerate, wacke, intermediate to mafic massive to schistose metavolcanics, and chert-magnetite-wacke iron formation. The supracrustals are cut by northeast- and northwest-trending diabase dikes.

In the southeastern portion of the map area the rocks consist of intermediate to felsic metavolcanics, intermediate to mafic metavolcanics, iron formations, and diabase dikes. The felsic metavolcanics consist of sericite schists, massive flows, lapilli tuffs, tuffs, and breccias. The mafic metavolcanics are breccias and massive and pillowed flows.

The iron formation at the Magpie Mine consists of siderite without the customary associated sulphide, chert, wacke, graphite, and oxide phases. The Alice iron range southeast of the mine is composed of chert-magnetite. The iron formation (Reynolds iron range) southwest of the mine consists of chert, magnetite, pyrite, and wacke.

The rocks in the area of the Magpie Mine are hard, brittle, and lack the usual pervasive carbonate alteration of the Wawa area. Some outcrops that have a rhyolitic appearance were interpreted by the field party as being silicified pillowed mafic metavolcanics.

Structural Geology

Aguonie Township

The central low-lying portion of the township is underlain by highly schistose to fissile intermediate to felsic metavolcanics. The higher ground is generally underlain by mafic intrusive rocks. While intermediate to felsic metavolcanics underlie most of the township, it is suspected that folding and faulting have resulted in repetition of an originally much narrower section of intermediate to felsic metavolcanics. A lack of facing directions and marker horizons has so far prevented delineation of the nature of this suspected folding and faulting.

On the basis of pillow shape the intermediate to mafic metavolcanics along the southern margin of the township face south.

Abotossaway Township

A lack of facing directions in the intermediate to felsic metavolcanics in the southeastern corner of the township prevents delineation of any structure. These rocks occur along the extrapolated extension of the Alden Lake anticline. Their highly schistose nature implies strong deformation. On the basis of pillow shapes within pillowed intermediate to mafic metavolcanics, the rocks above the Rand No. 2 iron formation face north.

Finan Township

The Herman Lake nepheline syenite and Maskinonge Lake granitic stock are cut by generally northeast-trending narrow zones (on the order of 1 m wide) of highly deformed rock displaying good fluxion structure. These zones are interpreted as mylonite zones.

Pillow shapes within intermediate to mafic pillowed metavolcanics at the eastern end of the area indicate that the sequence faces north.

Leclaire Township

An anticlinal structure has been previously outlined within Leclaire Township (Sage 1982). Mapping in the northeastern corner of the township and on the northern limb of the anticlinal structure failed to uncover reliable facing indicators to confirm this structure. Stretched cobbles in the conglomerates and the highly schistose nature of the metasediments and metavolcanics implies local strong deformation. On the basis of pillow shape in intermediate to mafic flows, 2 to 3 km southwest of the Magpie Mine, the sequence faces southwest. This is consistent with the interpretation of an anticlinal structure being present.

In the vicinity of the Magpie Mine the presence of undeformed coarse angular fragments, approaching 1 m in maximum dimension, in the breccias suggests that they were deposited proximal to a vent area. The relatively undeformed nature of these breccias contrasts sharply with the schistose rocks north and south of the mine area. The rocks in proximity to the mine are hard, brittle, and appear silicified. This silicification has produced a more competent rock which has locally been relatively undeformed. Tectonic adjustments have undoubtedly taken place in the unsilicified rocks surrounding the mine area.

Economic Geology and Recommendations to Prospectors

Aguonie Township

Several minor barren pyrite horizons were noted by the field party. These almost always occur at the contact between the intermediate to felsic metavolcanics and mafic intrusive rocks.

The mafic intrusive rocks, if more mafic phases can be identified, have a limited potential for disseminated copper-nickel mineralization similar to that found at Elbow Lake in Esquega Township.

The intermediate to felsic metavolcanics are typical of those found close to many massive sulphide base metal deposits in Ontario and Quebec, but massive sulphide horizons are not known to exist in the section mapped. Prospecting in the area should routinely sample quartz veins for their gold content; gold-bearing quartz veins appear to offer the best target for exploration within the area examined.

Abotossaway Township

The galena-sphalerite quartz veins carrying gold and silver values appear to be restricted to the Kozak Occurrence. Prospectors working in this area should look for similar occurrences in other areas of the Alden Lake Volcanic Centre.

Iron formations of the area should be checked for their gold content.

Finan Township

The Herman Lake nepheline syenite and Maskinonge Lake granitic stock were not observed to contain mineralization. There is no known mineralization within either of these stocks. Neither stock appears to offer a good exploration target. The nepheline is commonly altered to cancrinite and appears to be of little commercial interest.

The very limited amount of mafic metavolcanics examined contain minor pyrite and warrant prospecting for gold.

Leclaire Township

The rocks in the northeastern corner of the township are favourable to gold deposits, and base metals may occur within the mafic metavolcanics. The iron formations have been tested for their iron content but not for base metals or gold.

The southeastern corner of Leclaire Township would appear to offer one of the better areas for prospecting. Both the pervasive silicification indicating an active hydrothermal system, and the presence of coarse breccias implying a proximal vent source, suggest a highly favourable area for prospecting for base metals. The iron formations of the area, for example the Reynolds iron formation, warrant checking for gold.

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No. S11 Mishewawa Lake Area, District of Algoma

N.W.D. Massey[1]

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Introduction

Field investigations carried out in 1983 represent the second part of a 2-year project initiated in 1982 (Massey 1982) to map the geology of the Mishewawa Lake area, situated south and west of the Town of Wawa. Work in 1982 was concentrated in Rabazo and Naveau Townships. In 1983 work was extended eastward into Nebonaionquet Township and northwestward into Lendrum Township and Gros Cap Indian Reserve. About 160 km^2 of ground was covered.

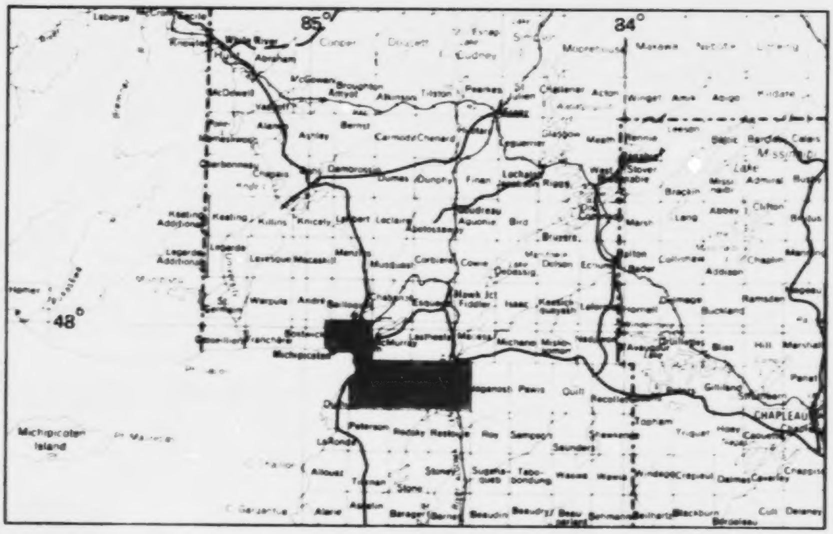
Access into Nebonaionquet Township is provided by a good all-weather road running south from Highway 101 to Anjigami Station. A series of gravel roads run south and east from here. The main track of the Algoma Central Railway runs approximately north-south through the centre of the township. Western Nebonaionquet and southeastern Naveau are accessible from Anjigami Lake or by 4-wheel drive vehicle, westward from Anjigami Station or southward from McPhail Falls.

The Trans-Canada Highway (Highway 17) passes along the eastern side of Lendrum Township. A good all-weather road runs from Michipicoten Mission to Michipicoten Harbour and Indian Beach. A spurline of the Algoma Central Railway runs from Michipicoten Harbour northeastward through Trembley Flats.

Mineral Exploration

Exploration for gold, base metals, and iron has been carried out within the Mishewawa Lake area since the Wawa camp opened in 1897. Only 3 deposits have ever produced: the Norwalk, Centennial, and Ranson Mines (*see* Massey 1982 for further details).

Prospecting activity in Nebonaionquet and Lendrum Townships has mainly centred on the iron formations. The Anjigami Lake Iron Formation was originally discovered at the turn of the century and has undergone several investigations since. It is too small to be of much value for iron, though associated sulphides suggest the possibility of gold or base metal mineralization. The Gros Cap Iron



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

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[1] Geologist, Precambrian Geology Section, Ontario Geological Survey, Toronto

Formation was first investigated in the 1860s and again in 1916 and 1918. It is a banded chert and hematitic ironstone, but too lean to be of commercial value.

In recent years mineral exploration has been directed towards the search for gold and base metals both in quartz veins and sulphide iron formations. In 1980 to 1981 the Algoma Steel Corporation Limited investigated 3 blocks of claims in Lendrum Township, and some smaller properties in Rabazo and Naveau Townships for base metals and gold. A large claim block in Naveau and Nebonaionquet Townships was explored by Noranda Exploration Company Limited for gold in 1981 to 1982. An exploration program for gold and base metals was undertaken by the Department of Indian and Northern Affairs, Indian Minerals (East) Directorate in 1982 to 1983 on behalf of the Gros Cap Indian Band.

During 1983, mineral exploration activity, primarily directed to the search for gold, was high and all available ground has been staked and claimed. This resurgence in activity has been prompted by findings in the nearby Hemlo camp. New assessment and development work is proceeding on the Ranson Mine, Gold Monk Mine, and Roller Lake in Rabazo Township, the Centennial Mine in Naveau Township, and the Osisko Lakes Mines property in the northern part of Lendrum Township.

General Geology

The Mishewawa Lake area forms the southwestern end of the Wawa "Greenstone Belt". Mapping was restricted mainly to areas underlain by supracrustal rocks (Figure 1).

The mafic metavolcanic succession shows a general progression from massive flows at the base, upwards into pillowed lavas (some variolitic), pillowed lavas and tuffs, and finally tuffs and chlorite schists.

Felsic metavolcanics consisting of intermediate to felsic flows, tuffs, and crystal tuffs, occur sporadically throughout the upper part of the mafic metavolcanic sequence. Thicker sequences of felsic flows, tuffs, crystal tuffs, lapilli tuffs, and breccias occur east of Moon Lake in Naveau and Nebonaionquet Townships, and in the eastern half of Lendrum Township (north of Trembley Flats and in the Legarde Hill area).

Chemical metasediments consisting of chert and banded iron formation, usually oxide facies, occur in several localities. Most of these occurrences are restricted in thickness and strike length, although more extensive iron formations occur north of Mishewawa Lake, extending east-southeast towards Anjigami Lake, and on the southwest corner of Gros Cap Peninsula. They occur interlayered with both mafic and felsic metavolcanics.

Clastic metasediments of the "Doré Series" (Logan 1863) form the northern margin of the supracrustal belt in Lendrum Township and the Gros Cap Indian Reserve. They consist of poorly-sorted, polymictic conglomerates with wacke and occasional arkose and argillite. Felsic metavolcanic interbeds are also found.

Gabbroic intrusions of probable Early Precambrian (Archean) age are common in the area, both as sub-concordant sills within the mafic volcanic pile and as large cross-cutting stocks. Felsic bodies, of granodiorite or feldspar porphyry, intrude the metavolcanics. Minor felsic dikes are also present.

Diabase and lamprophyre dikes of probable Keweenawan age cross-cut the area.

The metavolcanic sequence is probably correlative with the "Lower Cycle" metavolcanics of McMurray and Chabanel Townships (Sage 1981), although some mafic metavolcanics in Lendrum Township may belong to the "Middle Cycle" (Sage 1981), as do the "Doré Series" metasediments.

Structural Geology

Metavolcanics within the supracrustal sequence show evidence of at least 2 phases of deformation. The first produced a foliation that is commonly subparallel to bedding, where bedding is discernible, but which can be seen to be axial planar to small folds within tuffs and schists. This first foliation is pervasive and dominant within most of the area, commonly trending 100° to 125° with a steep dip. In northern and central Lendrum Township, however, the foliation trends 040° to 060° with moderate to steep southeasterly dips.

The first foliation was deformed by a second event which produced crenulation and fracture cleavages. This second foliation is variable in development and trend.

The distribution of lithologies and variations in dips and strikes outline 3 major folds. The belt of clastic metasediments in Lendrum Township and Gros Cap Indian Reserve, occurs within a syncline overturned to the northwest, resulting in inverted strata on the limb. Both metasediments and mafic metavolcanics show younging in a northwesterly direction, coupled with southeasterly dips of bedding and foliation. A somewhat asymmetric anticline is situated to the south of the syncline, with its southern limb showing the dominant east-southeast trend of bedding and foliation.

Within Naveau and Nebonaionquet Townships, dips of the metavolcanics, though always steep, vary from southwesterly in the north to northeasterly in the south. This configuration, coupled with the presence of felsic metavolcanics in the centre, suggests an upright, isoclinal synform.

Several major faults cut the area. The Trembley Fault trends northwesterly and has a sinistral offset. Bending of beds due to drag is apparent close to this fault northwest of Trembley Flats. Some bifurcation of the fault is also apparent west of Trembley Flats. The Agawa Canyon Fault runs northward through Nebonaionquet Township, to the west of Anjigami Lake, and effectively marks the eastern limit of the supracrustal rocks in the map area.

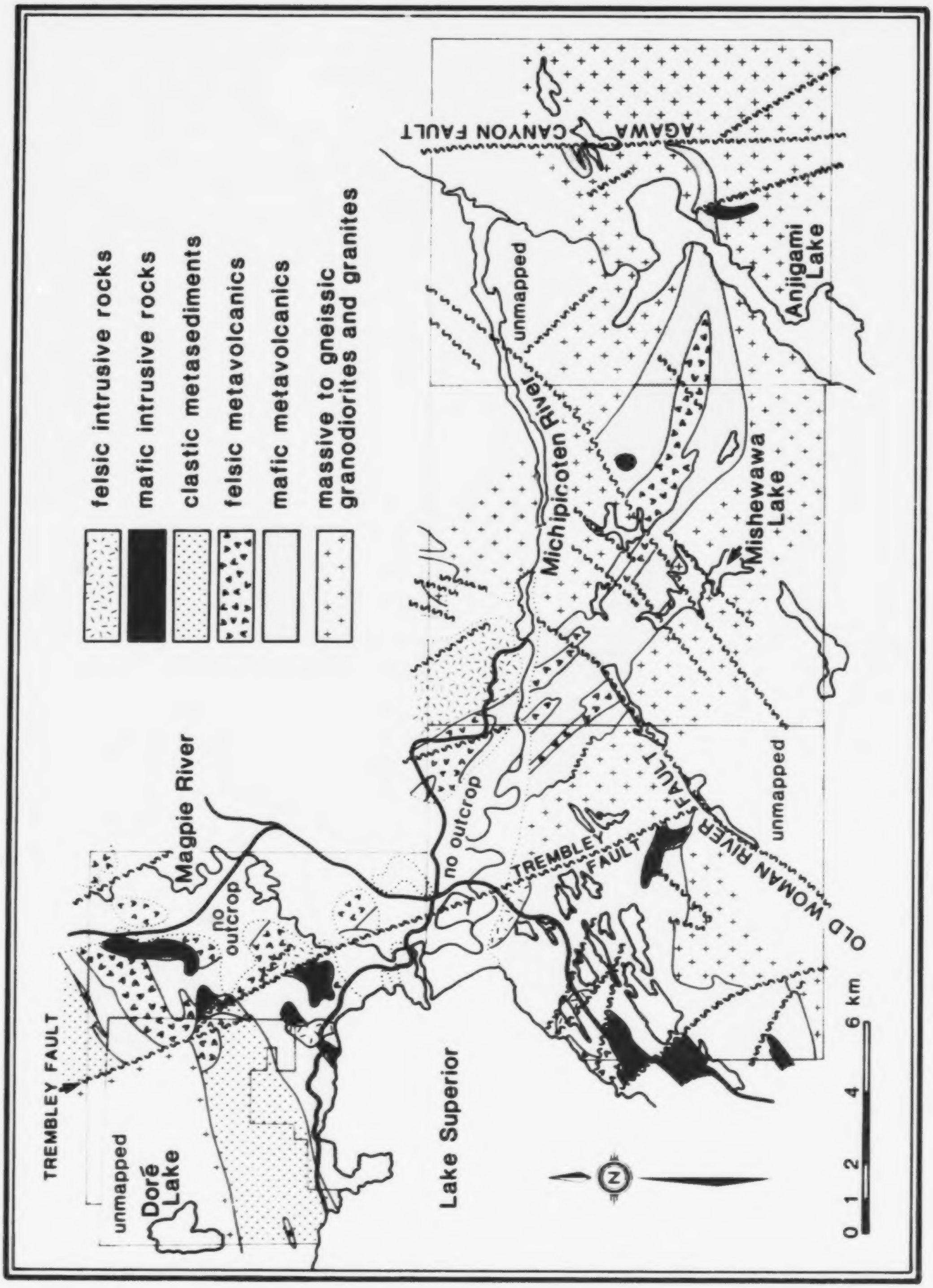
felsic intrusive rocks
mafic intrusive rocks
clastic metasediments
felsic metavolcanics
mafic metavolcanics
massive to gneissic granodiorites and granites
TREMBLEY FAULT
unmapped
Doré Lake
Lake Superior
Magpie River
no outcrop
no outcrop
TREMBLEY FAULT
OLD WOMAN RIVER FAULT
unmapped
Michipicoten River
Mishewawa Lake
unmapped
Anjigami Lake
AGAWA CANYON FAULT
N
0 1 2 4 6 km

Figure 1. Geology of the Mishewawa Lake area

Economic Geology

Gold

Gold mineralization within the Mishewawa Lake area is confined to quartz veins which either follow regional foliation or infill shears and faults. Host rocks vary from mafic to felsic metavolcanics, as well as felsic intrusive rocks. To date, no mineralization has been recorded within the clastic metasediments. Disseminated sulphide mineralization is common in mafic metavolcanics and mafic intrusions throughout the area. Carbonate alteration of rocks is generally limited, but may be pervasive in felsic metavolcanics in Lendrum Township. Almost complete carbonatization of mafic pillow lavas is also found in parts of Gros Cap Peninsula.

Other Metals

Oxide iron formations within the area appear to be of little economic importance as far as their iron potential is concerned. Associated sulphide iron formations, however, may have some potential for gold and base-metal exploration, though they also are thin and discontinuous.

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No. 12 Batchawana Synoptic Project

E.C. Grunsky[1]

Introduction

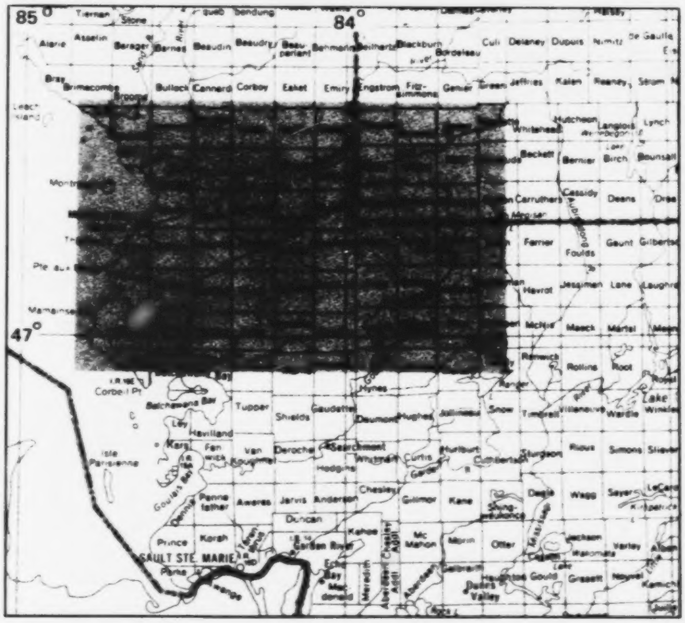
An on-going study of the Batchawana area was initiated in 1981 to integrate and summarize existing geological information, focusing on studies of geological environments, to aid in assessing the mineral potential of the area. Geological mapping at detailed and reconnaissance scales is being carried out in selected areas. These areas include both areas of known high mineral potential and previously unmapped areas. Field, economic geology, laboratory, and thin section data are being compiled in order to create a computer database which will allow for an integrated system of stored geological data for investigative and archival purposes.

The synoptic study has examined the stratigraphy, chemistry, geochronology, and structure of the Archean supracrustal assemblage, and the structure and ages of the surrounding felsic intrusive rocks. A review of the known mineral occurrences, deposits, and mines is being compiled. Emphasis has been placed on outlining areas of favourable mineral potential. In conjunction with this study, U-Pb (from zircons) age determinations are being carried out by the Royal Ontario Museum, Toronto. Some of the preliminary results are shown in Figure 1. A study of the paleomagnetism of the diabase dikes that occur in the area is being carried out at the University of Toronto under the direction of H.C. Halls.

A computer-based format for recording field data from a system developed by Lambert and Reesor (1974) was used for both the 1982 and 1983 field seasons. The end result of recording field data in this fashion will be a computer accessible file for all field observations of the Batchawana area that will be available for exploration and research purposes.

A compilation of existing geological maps and reports has been previously reported (Grunsky 1981b).

This present summary contains information obtained during the 1983 field season.


85°
84°
47°
Alarie
Asselin
Barnes
Beaudin
Bullock
Cannard
Corboy
Eaket
Emiry
Engstrom
Blackburn
Cull
Delaney
Dupuis
De Gaulle
Jeffries
Kalen
Reaney
Whitehead
Beckett
Bernier
Birch
Carruthers
Cassidy
Deans
Farrier
Foulds
Gaunt
Havrot
Jessiman
Lane
McNie
Maeck
Martel
Renwick
Rollins
Root
Corbeil Pt
Batchawana Bay
Tupper
Shields
Gaudette
Dumont
Hughes
Snow
Haviland
Isle Parisienne
Deroche
Hodgins
Curtis
Sturgeon
Simons
Chesley
Gillmor
Kane
Jarvis
Anderson
Awerea
Duncan
Prince
Korah
SAULT STE. MARIE
Goulais Bay
Otter
Wagg
Varley
Gould
Grasett
Lake Wabos

LOCATION MAP   Scale: 1:1 584 000 or 1 inch to 25 miles

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[1] Geologist, Precambrian Geology Section, Ontario Geological Survey, Toronto

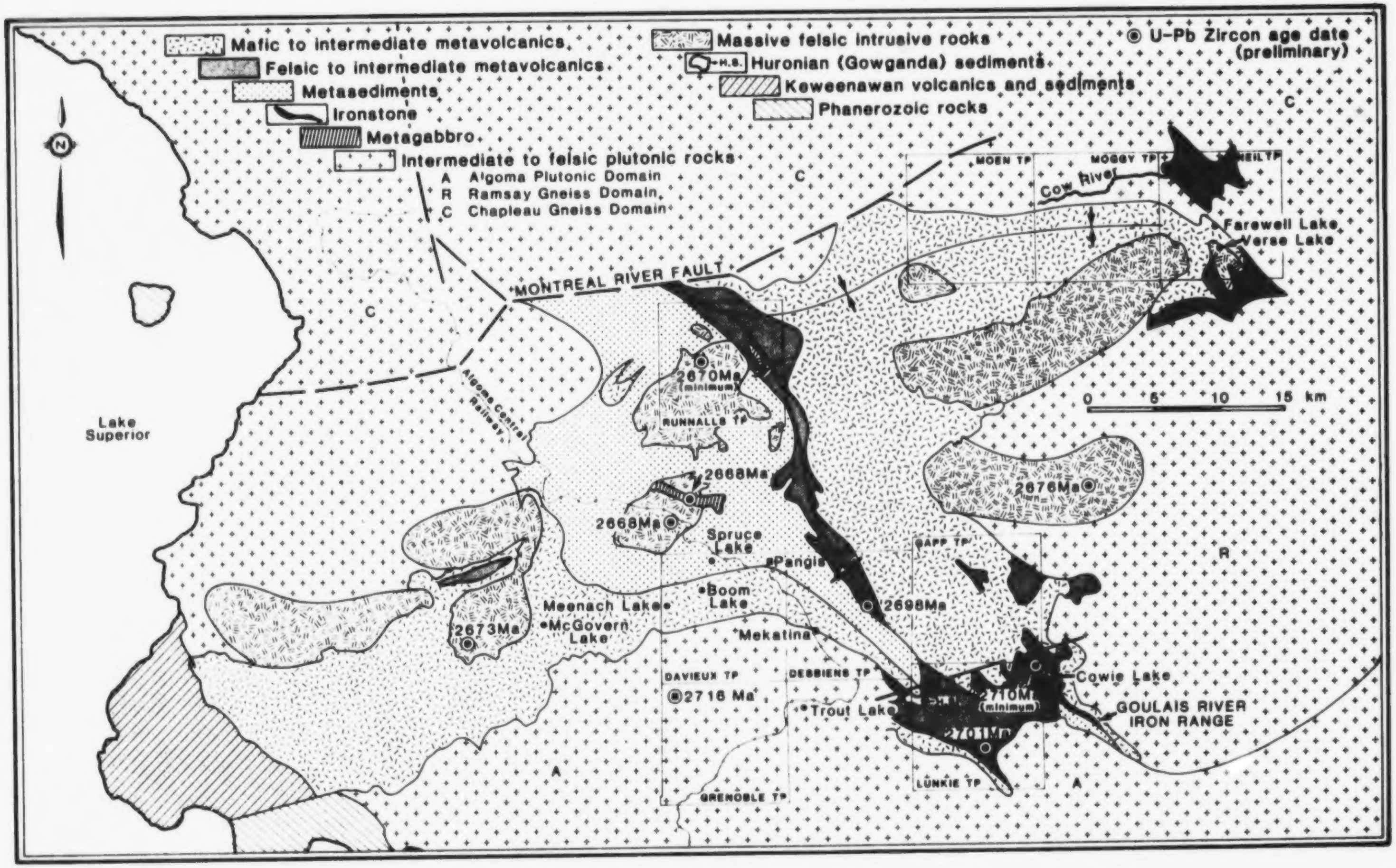
Mafic to intermediate metavolcanics
Felsic to intermediate metavolcanics
Metasediments
Ironstone
Metagabbro
Intermediate to felsic plutonic rocks
A Algoma Plutonic Domain
R Ramsay Gneiss Domain
C Chapleau Gneiss Domain
Massive felsic intrusive rocks
H.S.
Huronian (Gowganda) sediments
Keweenawan volcanics and sediments
Phanerozoic rocks
U-Pb Zircon age date (preliminary)
N
Lake Superior
C
C
C
R
A
A
MONTREAL RIVER FAULT
Algoma Central Railway
MOEN TP
MOBY TP
NEIL TP
Cow River
Farewell Lake
Verse Lake
0
5
10
15 km
2670Ma (minimum)
RUNNALLS TP
2668Ma
2668Ma
2676Ma
Spruce Lake
Pangis
Boom Lake
2698Ma
SAPP TP
Meenach Lake
McGovern Lake
2673Ma
Mekatina
DAVIEUX TP
2716 Ma
DESBIENS TP
Trout Lake
2710Ma (minimum)
2701Ma
Cowie Lake
GOULAIS RIVER IRON RANGE
LUNKIE TP
GRENOBLE TP

Figure 1 Generalized geology of the Batchawana area

Mineral Exploration

The current interest in exploration for gold has resulted in a number of companies investigating the Batchawana area. Massive Energy Corporation holds a substantial claim group in the Davieaux Township area, where a regional exploration program is being carried out. Evaluation of a gold occurrence previously known as the New Hiawatha Mines Occurrence is being carried out. Other precious- and base-metal occurrences are also being investigated by Massive Energy Corporation.

Investigation of reported gold occurrences in the Neill Township area is being carried out by Hollinger-Argus Limited. Gold occurrences reported in felsic metavolcanics and metasediments west of Verse Lake are being investigated by this company. The author also sampled several sites in this area for assay. The assay values were not available at the time of writing.

Noranda Mines Limited has been investigating regional high-grade metamorphic terrains in the eastern part of the map area for their precious and base-metal potential. These gneisses and migmatites might represent the "keels" of metavolcanic-metasedimentary sequences that have been intruded and assimilated by the felsic intrusive rocks.

Work was carried out by Noranda Mines Limited on a claim group near Hanes Lake, Gapp Township, in a volcanic sequence containing sulphide mineralization.

Mattagami Lake Exploration Limited has been working in the metavolcanic-metasedimentary areas in the Cowie Lake region of the Batchawana belt, examining precious and base-metal occurrences.

D.G. Innes and Associates Limited currently holds a number of claims in the Lunkie Township area where a number of sulphide occurrences were previously examined by HBOG Mining Limited in 1976.

Dejour Mines Limited carried out work on a claim group east of Meenach Lake in Davieaux Township. Trenching, mapping, and geophysical work were carried out on the property. The area is underlain by mafic and felsic metavolcanics with interbedded metasediments. The metavolcanics are principally composed of mafic flows and tuffs with interbedded felsic tuffs.

Manwa Exploration Limited holds a large claim group in the Doyle Lake area (Runnalls Township); however, at the time of writing no work has been reported.

Jonpol Explorations Limited has acquired the Tribag Mine from Dekalb Mining Corporation. No work has been reported on the deposit at this time.

General Geology

Metavolcanic and Metasedimentary Terrains

Davieaux Township Area

An investigation in the Davieaux Township area was carried out following renewed interest in a gold prospect east of Meenach Lake (Figure 1). Two sections across the area were traversed and sampled; one from Meenach Lake north to Spruce Lake, and the other on the Algoma Central Railway right-of-way from Mekatina to Pangis. The supracrustal rocks are principally mafic tuffs, flows, and interflow metasediments (wackes, mudstones), with minor intercalated dacitic tuffs. The environment of formation is interpreted as distal volcanic and deep water. To the south, mafic tuffs and flows predominate, however, farther up stratigraphy, to the north, the metasediments become increasingly more dominant representing the transition from a volcanic to sedimentary environment. Northward into the Wart Lake area, bedded siltstones, wackes, and conglomerates become predominant (Siragusa 1981). A broad band of intercalated felsic tuffs, mafic tuffs and flows, and wackes occur between Pangis and Mekatina and the Algoma Central Railway. The felsic tuffs are most commonly found in the transition zone between the predominantly mafic metavolcanic sequence and the mainly metasedimentary sequence. These tuffs and sediments are continuous westward; however, they become increasingly more mafic in composition west of Meenach Lake. Eastward, the felsic metavolcanics become increasingly dominant. This area may be a transitional zone between calcalkalic metavolcanics to the east and tholeiitic metavolcanics to the west.

Between Mekatina and Pangis, extending westward into Davieaux Township, are zones of carbonate alteration. The felsic metavolcanic tuffs are most notably altered to a buff grey colour and are very soft. Many mafic metavolcanic units are also carbonatized and display a bleached appearance.

Several samples were collected along both traverse lines for chemical analysis in order to aid in outlining any geochemically anomalous zones.

A previous discovery of gold (New Hiawatha Mines Occurrence) east of Meenach Lake (Boom Lake area) is being investigated by Massive Energy Corporation. The gold occurs in a pyrite-chert ironstone horizon, about 5 m wide, that is underlain by a massive mafic metavolcanic flow and overlain by felsic crystal tuff. The gold mineralization appears to be in part structurally controlled (discussed under Economic Geology). Two grab samples taken from the property by the author in 1982 contained 1880 and 2280 parts per billion (ppb) gold (Geoscience Laboratories, Ontario Geological Survey, Toronto).

Neill Township Area

Investigation of the supracrustal rocks in Neill Township was carried out as part of the regional compilation. New roads into the area (since 1980) have allowed for a more detailed examination of areas that were previously very difficult to gain access to. Previously, the only mapping or assessment was done by Keevil (1936). The area is comprised of a distal facies mafic metavolcanic and metasedimentary succession that extends from the west (Wilson 1983). Both east and west of Verse Lake is a 1 km thick sequence of felsic tuffs, siliceous wackes, arenites, mafic tuffs, and pillowed mafic flows. The felsic tuffs are typically sericitic, are commonly comprised of crystal fragments, and are interbedded with metasediments. They strike north and are steeply dipping. Pyrite is an abundant ubiquitous mineral throughout the sequence west of Verse Lake. Northwest of Farewell Lake the regional strike of the supracrustal sequence is easterly. The structural relationship between the areas west of Verse Lake and northwest of Farewell Lake is not yet known. The Verse Lake area is underlain by a granodioritic stock which is surrounded by the felsic supracrustal rocks, as shown on Keevil's map (Keevil 1936). The 1 km thick stratigraphic sequence west of Verse Lake was sampled by the author. A local prospector has reported gold values from several sites within the sequence. Northwest of Farewell Lake along the road from Cow River, a 30 m thick exhalite zone contains abundant pyrite, pyrrhotite, with associated silicified metavolcanics. This area was also sampled. Further work is being planned for this area.

Intrusive and Metamorphic Terrains

Continuing reconnaissance mapping in the felsic plutonic terrains in the eastern, northeastern, and northwestern parts of the map was carried out.

The plutonic terrain can be divided into 3 broad terrains as outlined by Card (1979). The southernmost terrain is the Algoma Plutonic Domain (Figure 1), comprising massive felsic plutonic rocks, which occurs in the southeastern part of the map area.

The Ramsay Gneiss Domain is bounded to the south by the Algoma Plutonic Domain and to the north by the Chapleau Gneiss Domain. This terrain is characterized by massive and foliated felsic intrusive rocks composed of tonalite, trondhjemite, and granodiorite, and containing remnants of supracrustal rocks. The supracrustal remnants occur as amphibolite and quartz-plagioclase-biotite gneisses. The boundaries are typically gneissic against the plutonic rocks. Larger remnants contain migmatitic cores as biotite-rich and hornblende-rich units. The prevailing strike is northeasterly.

The northernmost terrain is the Chapleau Gneiss Domain, characterized by extensive migmatite and partially assimilated supracrustal rocks. Domes of felsic intrusive rocks occur north of the Montreal River. The dominant strike of the rocks is easterly. The boundary between the Ramsay Gneiss Domain and the Chapleau Gneiss Domain is delineated by the Montreal River Fault which defines the southern boundary of the Kapuskasing Structural Zone (Card 1979). The metamorphic mineral assemblages typical of the Chapleau Gneiss Domain in the map area is that of quartz + plagioclase ± biotite ± hornblende ± garnet. Garnet is not an abundant phase. These mineral assemblages most probably reflect compositional variations of the original rocks rather than being an indication of metamorphic grade. The metamorphic grade of this domain is variable from east to west (Percival 1983; Card *et al.* 1980) however it is interpreted to be of amphibolite rank within the map area.

Age Dating

During the 1982 and 1983 field seasons, 24 sites were sampled for U-Pb Zircon age dating (Figure 1). At this time only preliminary figures are available (F. Corfu, Geochronologist, Royal Ontario Museum, Toronto, personal communication, 1983). The calcalkalic metavolcanics in the eastern part of the map area, in a section from Cowie Lake southwest to Trout Lake, range from approximately 2710 to 2701 Ma. This cycle of metavolcanics overlies the magnetite-chert ironstone and represents the time interval when most of the metavolcanics in the eastern part of the map area accumulated. An earlier, only partly preserved, cycle beneath the ironstone was sampled this year in an attempt to determine its age. During the 1983 field season, a site near McGovern Lake was sampled in order to determine the age of the tholeiitic group of volcanic rocks in the western part of the map area. The oldest felsic intrusive rock, dated 2716.8 Ma, occurs in Grenoble Township (Figure 1) in what Card (1979) terms the Algoma Plutonic Domain. This indicates that plutonic activity was occuring prior to, or during, the bulk of volcanic activity to the northeast. All of the other massive plutons that occur within the Batchawana belt and adjacent to the east indicate ages of approximately 2770 to 2780 Ma. Other dates are still to be determined.

Paleomagnetic Studies: Diabase Dikes

A study is being conducted at the University of Toronto by E. Shaw under the direction of H.C. Halls on the paleomagnetism of the diabase dike swarm(s) that intrudes the map area. Three traverses across the map area have been carried out. Ten sites have been sampled along the Montreal River, approximately forty sites from Saymo Lake westward to Mekatina on the Algoma Central Railway right-of-way, and a few sites westward from Batchawana Station to Lake Superior. Preliminary work indicates that at least some dikes have a paleomagnetic signature different from the Matachewan swarm.

Economic Geology

Discussions of the economic potential of the Batchawana area have been discussed previously (Grunsky 1982, 1981b).

Areas with favourable base-metal mineralization potential are located in the Gapp-Lunkie Townships area (Grunsky 1980) where the mafic metavolcanic-felsic metavolcanic interface hosts a number of base-metal sulphide occurrences. This potentially favourable area extends northwestward into Desbiens, Way-White, and Runnalls Townships. Several base-metal and precious-metal occurrences occur in felsic tuffs around the Doyle Lake area (Grunsky 1981a). This sequence of metavolcanics extends approximately 35 km along strike and warrants detailed examination. The environment becomes increasingly proximal to the southeast. Base-metal sulphide potential also exists in the metavolcanic sequence east of Meenach Lake where felsic-mafic metavolcanic units are interbedded with sulphide-chert ironstone (exhalite type) horizons. To the northeast, a similar sequence of metavolcanics occurs in the Moen-Moggy-Neill Townships area. Although a distal facies environment is suggested for both areas, the presence of existing base-metal showings indicates further work may be warranted.

With the recent increase in exploration activity for gold, a number of companies have focused attention on the Batchawana area. Gold has been reported in Davieaux Township at the site of the old New Hiawatha Mines Property in association with a brecciated pyrite-chert ironstone underlain by a mafic flow and overlain by felsic tuffs. The unit is approximately 10 m thick, strikes east, and dips vertically. Several trenches have been dug, and sampling along the trench has been carried out by previous prospectors and by Massive Energy Corporation. From a limited number of observations, the gold is in quartz veins in faults that cross-cut the ironstone at a high angle. Further work is being carried out by Massive Energy Corporation.

Gold has also been reported in the Neill Township area, associated with pyrite-bearing felsic tuffs situated in a thick sequence of felsic tuffs, metasediments, and mafic flows. The area west of Verse Lake appears to have the greatest potential at this time. Very little is known about the geology of this area. The sulphide-rich tuffs strike southerly and dip vertically, with a 1 m wide quartz-feldspar porphyry dike intruding along strike. A local prospector has indicated significant gold values. The author has sampled several localities to determine their gold content. The results were not available at the time of writing.

Examination of the felsic metavolcanic terrain in conjunction with plutonic rocks, as in the Neill Township area, may have significant potential for gold occurrences. Other similar areas occur west of Morrison Lake, Lunkie Township, in the eastern part of Dablon Township, and Gaudry Township east of Point Lake.

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Grunsky, E.C.

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No. S13 Black River-Matheson Area, District of Cochrane

N.F. Trowell[1] and Robert Johnstone[2]

THIS PROJECT IS PART OF OPERATION BLACK RIVER-MATHESON (BRiM) WHICH WAS FUNDED EQUALLY BY THE ONTARIO MINISTRY OF NORTHERN AFFAIRS AND THE ONTARIO MINISTRY OF NATURAL RESOURCES.

Introduction

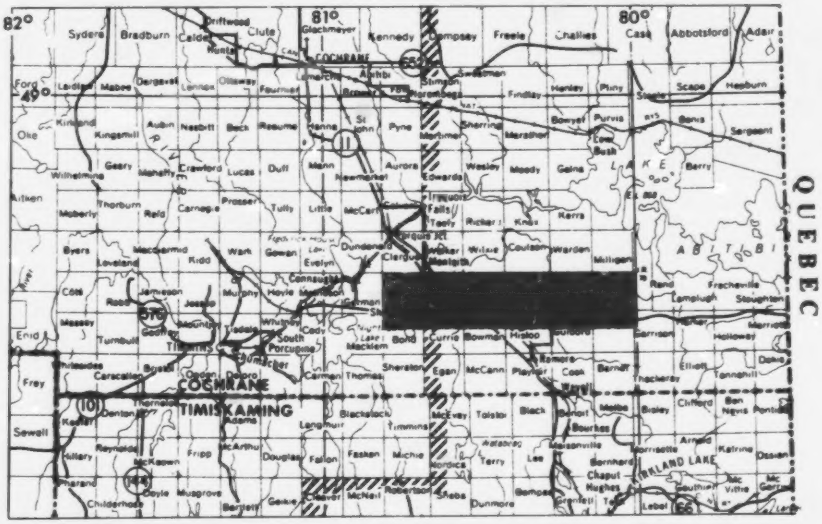
Field work done in 1983 represents the second year of a multi-year program to carry out detailed, synoptic, and stratigraphic mapping along the Destor-Porcupine Fault from east of Timmins to the Quebec border.

The townships of Stock, Taylor, Carr, and parts of Bond, Currie, and Bowman were mapped in 1982 (Trowell 1982). Beatty and parts of Munro Townships were mapped in 1983. The Town of Matheson is situated in the east-central part of the area and Timmins is approximately 60 km to the west. Highways 11 and 101 pass through the central part of the map area. Concession roads provide access to the western part of the map area, while central and east-central Beatty and west-central Munro Townships are best accessible by helicopter.

Mineral Exploration

Unless otherwise stated, the information reported here on exploration activity was obtained from the Resident Geologist's Files, Ontario Ministry of Natural Resources, Kirkland Lake, or Assessment Files Research Office, Ontario Geological Survey, Toronto (AFRO).

In any consideration of mineral exploration in the map area, it should be pointed out that with the exception of Munro and to a lesser extent Beatty Townships, the remainder of the area has from <5 to <1% outcrop. Overburden, primarily varved clay, varies in depth from a few metres to in excess of 60 m. Exploration, primarily for gold but also for base metals and asbestos, that began at the turn of the century, usually involved initial geophysical surveys: magnetometer and often electromagnetic, with follow-up diamond drilling of anomalies. This procedure is reflected in the compilation of assessment work and mineral exploration given on the data series maps of Beatty (Lovell *et al.* 1973) and Munro Townships (Ploeger and Grabowski 1980). A compilation of assessment work



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles.

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and mineral exploration for Stock, Taylor, Carr, Bond, Currie, and Bowman Townships is given in Trowell (1982).

In the western part of the area, the majority of the exploration has been directed towards delineation of, and selection of anomalies in the vicinity of the Destor-Porcupine and Pipestone Faults. Diamond drilling along these structures indicates the presence of a sequence of ultramafic and mafic rocks which are locally cut by gold-bearing quartz-carbonate veins and stringers. These rocks were likely originally volcanic flows, of komatiitic affinity, that were subsequently altered to various carbonate, chlorite, talc, and serpentine-bearing schists. Sulphide minerals, specifically pyrite and arsenopyrite but also galena, sphalerite, and chalcopyrite, are reported to accompany the gold. Metasediments, including chert, graphitic horizons, and conglomerates and wackes of ultramafic composition situated along these faults are also reported to contain gold mineralization. In Beatty and Munro Townships, exploration, in addition to being directed towards these fault structures, has covered almost the entire area of rock exposures, which is substantial. Also, exploration has been directed to the search for base metals and asbestos in addition to gold. There are 6 past producers in the area.

The former mines of Aljo Mines Limited (42 ounces of gold from 2333 tons of ore milled, Satterly and Armstrong 1949) and Argyll Gold Mines Limited (30.23 ounces of gold from 25 tons of ore milled, Satterly and Armstrong 1949) comprise fracture-filled gold-bearing quartz veins that cut tholeiitic flows in northwestern Beatty Township. There are mafic to ultramafic intrusions in the vicinity of both deposits. Maude Lake Gold Mine Limited is presently developing the former Argyll Gold Mines Limited property (Bob Bennett, Maude Lake Gold Mine Limited, personal communication, 1983).

The Croesus Mine (14 859 ounces of gold and 1423 ounces of silver from 5333 tons of ore milled, Satterly 1952) is a quartz vein deposit situated near the top of a sequence of iron-rich tholeiitic basalts in southwestern Munro Township. The richest ore occurred where the quartz vein cut pillowed and brecciated flow units that contain substantial interstitial sulphide mineralization (pyrite, pyrrhotite, arsenopyrite). The Munro Mine (355 819 tons of asbestos fibre valued at $57 196 467 from 1950 to 1964, Vos 1971) is situated within a differentiated ultramafic to mafic sill (thick flow?) concordant to tholeiitic and komatiitic flows in southwestern Munro Township (Hendry 1951; Freeman 1956). Exploitation of this deposit was by both open pits and underground shafts.

Potter Mine, in central Munro Township (1967 to 1972, 447 572 tons of ore milled with average grade of 1.63% Cu, 1.5% Zn, 0.1 to 0.5 ounce Ag, Coad 1976), is situated in olivine tholeiitic hyaloclastites near the northern margin of the Centre Hill Complex.

Potterdoal Mine, in north-central Munro Township (18 371 pounds Cu and 56.33 ounces Au from 1913 tons milled, Satterly 1952), is situated at the contact between tholeiitic basaltic lavas and overlying peridotite cumulate of a komatiitic flow ('Fred's Flow', Arndt 1975).

Two additional deposits, the American Eagle and White-Guyatt, in 1911 produced 40 and 10 ounces of gold, respectively. Both deposits are quartz vein deposits hosted by carbonatized and/or sericitized wacke in southern Munro Township.

General Geology

Beginning with Hopkins (1915), several individuals have described the geology of various parts of the map area (Knight *et al.* 1919; Moore 1937; Satterly and Armstrong 1949; Satterly 1952, 1960a, 1960b; Prest 1952; Leahy 1961, 1965).

All consolidated rocks with the exception of Keeweenawan (Abitibi Dyke Swarm) diabase dikes are of Early Precambrian (Archean) age. They consist of a metavolcanic-metasedimentary assemblage intruded by mafic to ultramafic plutons and dikes, granitoid dikes, diabase (Matachewan Dyke Swarm), and lamprophyres.

The metasediments occupy an east-trending belt bordered to the north and south by, respectively, the Pipestone and Destor-Porcupine Faults. They consist of sandstone, variable from arenite to feldspathic wacke, siltstone, and minor mudstone. They were likely deposited by turbidity currents. Metasediments of ultramafic composition, chert, and graphitic horizons are reported from diamond-drill holes (AFRO) along both faults. Crossbedded conglomerates and sandstones reported from diamond-drill holes in the southwestern part of the area (AFRO) were possibly deposited in a fluviatile or alluvial fan environment.

The metavolcanics to the south of the metasediments consist of intercalated iron-rich tholeiitic and tholeiitic flows (in 1982 these were mapped as magnesium tholeiites but initial chemical data suggest they are more 'normal' tholeiites) with the iron-rich tholeiites increasing in abundance to the south. The metavolcanics to the north of the metasediments comprise a lower sequence of high-iron tholeiitic flows exposed mainly in southeastern Beatty and in Munro Townships, and an upper sequence consisting of tholeiitic, komatiitic, and iron-rich tholeiitic flows. While these various types of flows of the upper sequence can generally be distinguished, based upon their flow features and apparent chemistry, delineation of the various chemical suites, except to state that Munro Township is underlain predominantly by rocks of the komatiitic suite, awaits further chemical data.

A mafic to ultramafic intrusion consisting predominantly of pyroxenite with minor gabbro and peridotite intrudes the metavolcanics north of Painkiller Lake. A sheared peridotite dike intrudes the pillowed flows situated just south of the shaft of the former Argyll Gold Mines Limited Property. This dike may occupy the eastward extension of the Pipestone Fault. A serpentinized gabbro body is located within the northwestern corner of Stock Township. The

Munro-Beatty sill (thick flow?), a differentiated ultramafic to mafic sill, hosted the Munro Mine asbestos deposit. Fred Wicks (Royal Ontario Musuem, Toronto, personal communication, 1983) is continuing his studies of the rodingite dikes that intrude the Munro-Beatty sill. A layered mafic intrusion, the Centre Hill Complex (MacRae 1963), is located in central Munro Township, while Warden Hill, a massive homogeneous gabbroic intrusion, is located in northwestern Munro Township.

A number of feldspar (plagioclase) porphyries cut the metasediments, metavolcanics, and ultramafic to mafic intrusions. They range in composition from leucotrondhjemite to quartz leucogabbro. They can rarely be traced for more than a few 10s of metres before they either pinch or are faulted out. They are locally mineralized containing pyrite and uncommonly chalcopyrite. Some of these dikes may be apophyses of larger, covered, granitoid bodies.

North-northeast- to north-northwest-trending Matachewan diabase dikes cut all lithologies of the supracrustal sequence. Compositionally, they are quartz diabase; texturally they vary from equigranular to feldspar (glomero)-porphyritic. They vary in width from <15 cm to upwards of 100 m. They are commonly but not always, magnetic. Two northeasterly to slightly east-northeasterly trending Keweenawan diabase dikes cut both the supracrustal sequence and the Matachewan diabase dikes. Compositionally, they are olivine diabase and are coarse grained equigranular to slightly (plagioclase, pyroxene) porphyritic.

Lamprophyre dikes, perhaps of more than one age, cut all other lithologies.

Metamorphic rank ranges from prehnite-pumpellyite facies in Beatty Township to lower greenschist facies rank to the west and south. Actinolite-epidote bearing assemblages overprint the prehnite-pumpellyite bearing assemblages in the contact aureoles of assumed buried granitoid bodies and along shear zones. Intrusion of diabase dikes has hornfelsed a few metres of the host rocks.

Local areas of metavolcanics have been effectively silicified by the leaching out of mafic minerals. On the property of Maude Lake Gold Mine Limited (formerly Argyll Gold Mines Limited), a zone of pillowed flows and pillow breccia have a yellowish to creamy hue due to leaching out of the mafic minerals and the development of sericite and of iron-rich brown carbonate.

Carbonatization and the development of talc, chlorite, serpentine, and locally sericite is a prevalent alteration of ultramafic rocks situated along the Destor-Porcupine Fault (AFRO).

Structural Geology

The supracrustal sequence has not been penetratively deformed. Locally, a schistosity or shear zones have developed due to fault movement. The 2 major faults in the area are the Destor-Porcupine Fault and the Pipestone Fault. The Destor-Porcupine Fault is both a lithological and structural discontinuity as it separates metasediments to the north from metavolcanics to the south, and is itself localized along a zone of sheared ultramafic and associated mafic rocks. The Pipestone Fault in the western part of the area defines the contact between metasediments to the south and metavolcanics to the north, whereas to the east in eastern Carr and Beatty Townships, it separates 2 metavolcanic assemblages. Other faults developed parallel to stratigraphy have been offset by later northeast-trending faults. Diabase dikes (Matachewan) were in many cases emplaced along north-northwesterly to north-northeasterly trending faults. Late northwest- to north-northwest-trending faults appear to offset all earlier structures.

Opposing facing directions indicate that the supracrustal sequence has been folded, but due to the lack of outcrop, with the exception of Beatty Township, the accurate placement of axial plane traces of folds is not possible. The authors suspect that rather than dealing with tight isoclinal folding, the structural development of the area might reflect synvolcanic buckling of the supracrustal sequence combined with low angle thrust or listric normal faults (C.J. Hodgson, Professor, Queen's University, Kingston, Ontario, personal communication, 1983).

Economic Geology

Both the ultramafic and associated mafic rocks, and the metasediments along the Destor-Porcupine and Pipestone Faults represent viable exploration targets, specifically for gold mineralization. Paucity of outcrop and impermeable clay cover preclude geological and some geophysical, for example Induced Polarization, exploration techniques. Overburden drilling with chemical and mineralogical analysis of basal till could be an effective prospecting method. As well, vertical-gradient magnetometer surveys combined with a knowledge of drift thickness might be useful in defining and thus screening out the effects of overburden cover and thus allow for more accurate delineation of structures and lithological distribution.

In areas of extensive outcrop, such as northwestern Beatty Township, attention should be directed towards the distribution of volcanic facies and the paleotopography of the flows and fragmental units. Hyaloclastite, pillow breccia, and interpillow hyaloclastite invariably contain 1% to uncommonly 3% sulphide mineralization consisting of pyrrhotite, pyrite, and locally chalcopyrite. Due to their greater initial porosity, these units were much more permeable than the massive and pillowed flows, and any mineralized solutions would have been focused through them. Places where there could be a possibility of finding accumulations of base and perhaps precious metals would be where hyaloclastite units abut against massive flows, such that any mineralizing solutions would tend to pond against the massive flows and, dependent upon chemical conditions, could precipitate out elements of economic interest. While no carbonaceous material was seen in these fragmental units, the presence of such would be a favourable factor, in that biological activity often has a control on deposition of base-metal sulphides. The authors would suggest that a systematic mapping and sampling program be done on these fragmental units not only for base but also precious metals.

At the moment, exploration for asbestos is probably not warranted. Since the past producers of gold and precious metals in the map area are situated in fracture-controlled gold-bearing quartz veins, attention should be directed towards accurate delineation of the fracture patterns in the area to, if possible, predict the location of those areas where quartz stockworks could have developed.

The presence of base-metal mineralization in the komatiitic suite of rocks (Potter and Potterdoal Mines) is perhaps indicative of a new association of base-metal Archean mineralization (Arndt 1975, Coad 1976).

While minor pyrrhotite ± pentlandite mineralization was locally observed by the field party in basal sections of some komatiitic flows, their nickel potential is at present unknown.

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No. 14 Kirkland Lake-Larder Lake Synoptic Mapping Project, District of Timiskaming

L.S. Jensen[1]

Introduction

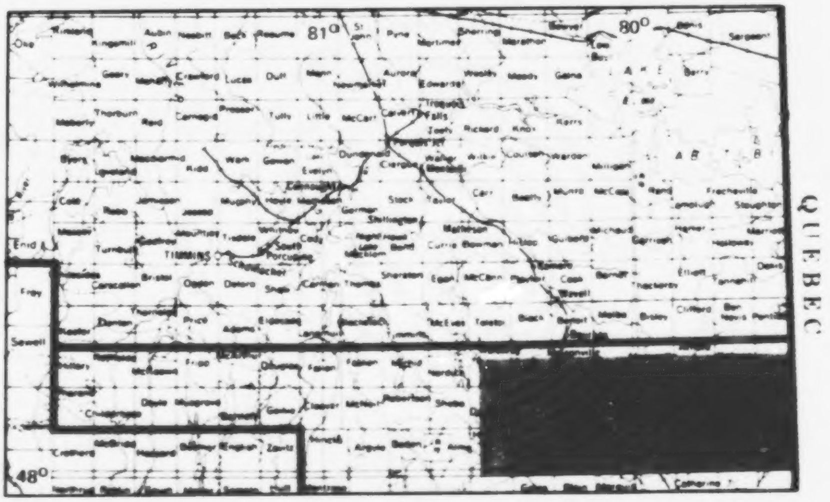
As a continuation of the stratigraphic synthesis of the Timmins-Kirkland Lake sheet, mapping in 1983 was concentrated in the Kirkland Lake map sheet at a scale of 1:63 360. Additional mapping was carried out in the Larder Lake sheet and in the Englehart area (*see* Jensen, this volume).

As a result of the regional mapping to date, a better understanding of the stratigraphy of the Ontario part of the Abitibi belt has evolved, so that areas of mineral potential can be better defined and further studied with the selection of specific detailed mapping projects (Jensen 1978a, 1978b, 1979, 1980; Jensen and Trowell 1981). The aim of this field season's work was to determine the paleo-environments of deposition of the metavolcanics and metasediments, as well as any subsequent alteration and tectonic deformation that may have affected the mineralization. Consequently, mapping was focused on the western extension of the Kirkland Lake-Larder Lake Fault Zone in the Kirkland Lake sheet between Matachewan and Kirkland Lake.

Mineral Exploration

Gold was initially discovered in the vicinity of Larder Lake in 1906 (Thomson 1943, p.40). Shortly thereafter, several gold mines were brought into production near Kirkland Lake, located 24 km west of Larder Lake, and numerous additional mines were brought into production during the period from 1920 to 1940. One mine, the Macassa Mine celebrated its 50th year of operation in 1983. As well, a new shaft is being constructed on the property adjoining the Macassa Mine by Willroy Mines Limited, Macassa Division.

Between 1950 and 1975, the emphasis has been on the search for base metals, iron, and asbestos. Recent fluctuations in the value of gold and silver have spurred new interest in exploring the area for precious metals. For



LOCATION MAP

Scale: 1: 1 584 000 or 1 inch to 25 miles recent mineral exploration in the Kirkland Lake area, refer to the report by Lovell, Grabowski, and Guindon (1983).

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General Geology

Bedrock in the area consists of Early Precambrian (Archean) metavolcanics, metasediments, and plutonic rocks. Middle Precambrian (Huronian) sedimentary rocks unconformably overlie the Early Precambrian rocks in parts of the area. Pleistocene deposits of till, esker deltaic sand, and varved clay mantle the bedrock throughout the area.

The volcanic succession in the Kirkland Lake area consists of successive volcanic piles, each composed of komatiitic rocks at the base, overlain in turn by tholeiitic and calc-alkalic rocks, and capped by alkalic volcanic rocks. Two such piles, plus the top of an older third pile, are preserved in the Kirkland Lake area. The successive piles together form a stratigraphic section > 50 000 m thick, with the uppermost pile being in excess of 35 000 m thick. The volcanic succession is preserved in a large east-plunging synclinorium 80 to 120 km wide (Jensen 1980).

The stratigraphy of the southern limb of the synclinorium is summarized in Table 1. The Kirkland Lake-Larder Lake Fault Zone intersects the southern limb of the synclinorium.

The refinement of the stratigraphy in the Kirkland Lake sheet from this season's field work is shown in Figure 1. The Pacaud tuffs, the lowermost unit of volcanic rocks, extend westward into Burt, Gross, and Flavelle Townships, along the margins of the Round Lake Batholith from Pacaud Township to the southeast (*see* Jensen, this volume). The Pacaud tuffs (Goodwin 1965) are finely bedded calc-alkalic andesite, dacite, and rhyolite tuffs and lapilli-tuffs that contain beds of iron formation, chert, and pyrite. Toward the top, the tuffs are interlayered with amphibolitized tholeiitic lavas.

The Wabewawa Group is represented by minor tremolitic komatiitic basalt which is interlayered with the amphibolitized tholeiitic lavas at the top of the Pacaud tuffs.

The tholeiitic basalts, situated above the Pacaud tuffs and Wabewawa Group, show a strong iron enrichment. They are considered to be a continuation of the Catherine Group situated west of the Otto Stock.

The calc-alkalic volcanic rocks of the Skead Group, along with some of the lower tholeiitic lavas of the Catherine Group, extend westward around the northern margin of the Otto Stock into Eby and Burt Townships, where they are covered by younger rocks of the Proterozoic Gowganda Formation. The Skead Group consists of calc-alkalic andesite, dacite, and rhyolite tuff-breccias and tuffs that contain zones of chert, iron formation, sulphide, and carbon (graphite).

Komatiitic and tholeiitic lavas of the Larder Lake Group succeed the Skead Group. They occupy a west-plunging syncline south of the Kirkland Lake-Larder Lake Fault Zone. The komatiitic and tholeiitic lavas are interlayered with conglomerate, wacke, and mudstone largely composed of detritus eroded locally from the komatiitic lavas.

Associated with the clastic rocks are chert, iron formation, graphite, carbonate, and thin dacite and rhyolite tuffs.

Westward, on the southern limb of the syncline, the Larder Lake Group wedges out against the Skead Group, and on the northern limb, the Larder Lake Group is cut off by the Timiskaming Group and Kirkland Lake-Larder Lake Fault Zone. In the core of the syncline, the Larder Lake Group is overlain by tholeiitic lavas, believed to be part of the Kinojevis Group, that has its main exposure to the north in Grenfell, Maisonville, Bernhardt, and Teck Townships. To the northeast, the Kinojevis Group is overlain by calc-alkalic lavas of the Blake River Group.

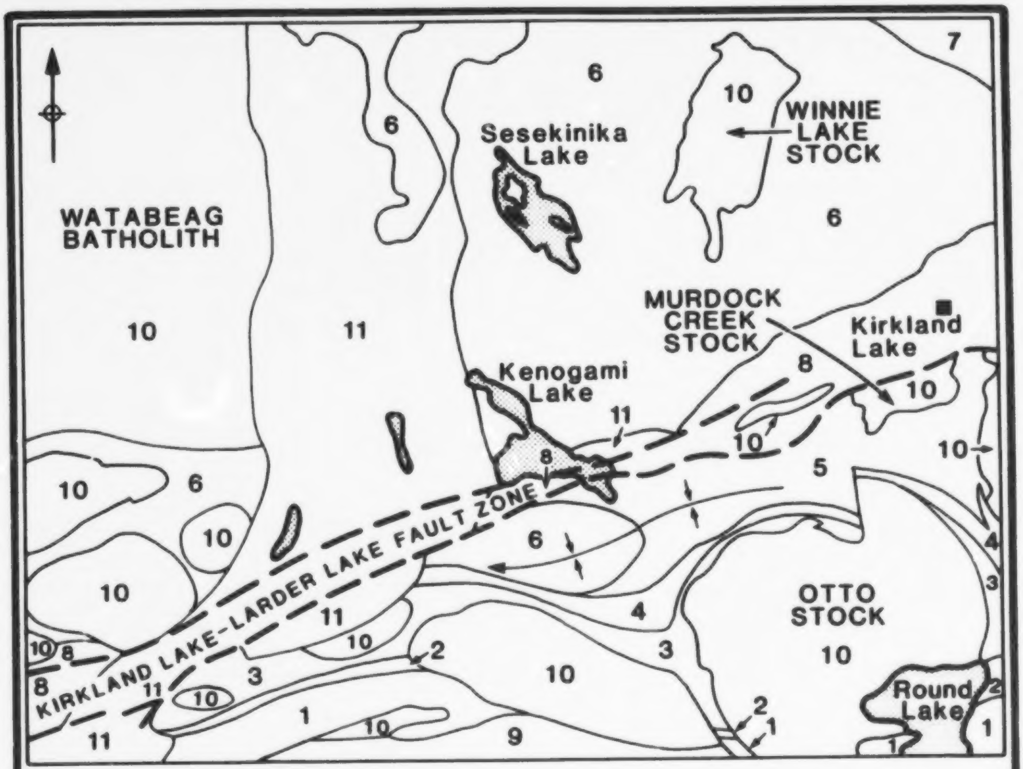
Additional tholeiitic lavas occur in southern Dunmore and northern Holmes Townships. These lavas are highly deformed and amphibolitized by the nearby granitoid intrusions. Interlayered with the tholeiitic lavas are calc-alkalic tuffs, tuff-breccias, and lapilli-tuffs of andesite, dacite, and rhyolite composition of similar metamorphic rank as the lavas. The tholeiitic lavas may be equivalent to the Kinojevis Group with the interlayered calc-alkalic rocks being derived from a volcanic source situated farther west. Until further stratigraphic mapping is carried out farther west, their stratigraphic position will remain uncertain.

The Timiskaming alkalic to subalkalic mafic to felsic volcanic rocks and their associated fluvial conglomerates, wackes, and mudstones unconformably overlie the Kinojevis Group in the eastern part of the map area near Kirkland Lake. They dip south and are juxtaposed by faulting against the Larder Lake Group. The Timiskaming Group is considered to have been deposited in a graben structure caused by faulting along the Kirkland Lake-Larder Lake Fault Zone.

Additional Timiskaming volcanic and sedimentary rocks not previously delineated by earlier mapping, occur in the southwestern part of Holmes Township. These rocks are alkalic to subalkalic, mafic volcanic flow breccias, tuff-breccias, and tuffs similar to those found in the vicinity of Kirkland Lake. Top determinations in the conglomerates found on the northern edge of the group suggest this volcanic succession faces south as does the Timiskaming Group in the Kirkland Lake area. These conglomerates contain clasts of mafic trachyte, chert, and other volcanic rocks, as well as a few cobbles of gneissic trondhjemite. No clasts of the nearby granitoid intrusions were observed.

The Round Lake Batholith occurs on the southern margin of the map area in contact with the Pacaud tuffs. It has a gneissic border in which the calc-alkalic tuffs and amphibolitized tholeiitic lavas have been transformed to fine-grained 'tonalitic' gneisses and gneissic diorites, respectively. Inward, the batholith becomes a more homogeneous gneissic trondhjemite.

Numerous late intrusions of mafic to felsic dikes, stocks, and sills intrude the metavolanics and the Round Lake


WATABEAG BATHOLITH
Sesekinika Lake
WINNIE LAKE STOCK
MURDOCK CREEK STOCK
Kirkland Lake
Kenogami Lake
KIRKLAND LAKE-LARDER LAKE FAULT ZONE
OTTO STOCK
Round Lake
1
2
3
4
5
6
7
8
9
10
11

11 Proterozoic Gowganda Formation
10 Late syenite, monzonite, granodiorite intrusions
9 Round Lake Batholith (trondhjemite)
8 Timiskaming Group
7 Blake River Group
6 Kinojevis Group
5 Larder Lake Group
4 Skead Group
3 Catherine Group
2 Wabewawa
1 Pacaud Tuffs

Figure 1 Kirkland Lake map area

TABLE 1 SOUTHERN LIMB STRATIGRAPHY

GROUP	VOLCANIC ROCKS	ASSOCIATED SEDIMENTS	ASSOCIATED INTRUSIVE ROCKS	RELATIONSHIPS
Timiskaming Group (Kirkland Lake-Larder Lake Section) 3000 m	Na- and K-rich mafic to felsic alkalic volcanic rocks and K-rich subalkalic felsic volcanic rocks	Fluviatile conglomerate, wacke, and argillite of material derived locally and from LLG	Mafic to felsic syenodiorite, syenite, monzonite, granodiorite, and lamprophyre	Unconformably overlies BRG, KG, and in places LLG. Mainly a fault contact with LLG
Blake River Group (BRG) 10 000 m	Calc-alkalic basalt, andesite, dacite, and rhyolite flows, and pyroclastic rocks. Minor Mg-rich tholeiitic basalt	Volcaniclastic turbidites derived by slumping off volcanic edifices	Gabbro, diorite, quartz diorite, and rhyolite domes	Conformably overlies KG
Kinojevis Group (KG) 10 000 m	Mg-rich and Fe-rich tholeiitic basalt with minor tholeiitic andesite, dacite, and rhyolite flows	Hyaloclastite and argillite, chert and graphite	Gabbro	Conformably overlies SG
Larder Lake Group (LLG) Thickness unknown est. 5000 m	Peridotitic and basaltic komatiite and Mg-rich tholeiitic basalt, minor Fe basalt, calc-alkalic rhyolite tuff toward base of group	Turbiditic conglomerate, wacke, argillite of material derived locally from komatiitic flows and distally from SG, graphite, carbonate, and iron formation	Dunite, peridotite, pyroxenite, and gabbro	Disconformably overlies CG
		Pebble conglomerate with syenite clasts	Syenite intrusion?	
Skead Group (SG)	Calc-alkalic basalt, andesite, dacite, and rhyolite flows and pyroclastic rocks	Cherts and iron formation	Rhyolite porphyries	Conformably overlies CG
Catharine Group (CG)	Mg-rich and Fe-rich tholeiitic basalt	Minor argillite	Gabbro	Conformably overlies WG
Wabewawa Group (WG)	Peridotitic and basaltic komatiite and Mg-rich tholeiitic basalt. Minor rhyolite tuff	?	Dunite, peridotite, pyroxenite and gabbro	Overlies calc-alkalic tuffs (Pacaud tuffs)
Pacaud Tuffs	Calc-alkalic andesite, dacite, and rhyolite tuffs	Cherts and iron formation		Truncated by the Round Lake Batholith

Batholith. The more mafic phases are represented by hornblendites and pyroxenites which form portions of the Otto Stock, Murdock Creek Stock, Watabeag Batholith, and some of the stocks in Holmes Township. The less mafic varieties include syenodiorite, monzonite, syenite, diorite, quartz diorite, quartz monzonite, and granite with variable but generally minor amounts of hornblende and magnetite present. A large variety of lamprophyres also occur. In contrast to the Round Lake Batholith, most of these later intrusive rocks have sharp contacts with the country rock.

The Proterozoic Gowganda Formation occupies a long north-northeast-trending salient that extends through Flavelle, Holmes, Burt, Bompas, and Lee Townships. The metasedimentary succession consists of a basal conglomerate of variable thickness overlain by a thick series of sandstone, siltstone, and mudstone beds. Toward the top of the succession, are wackes and sandstones with conglomerate phases. Sparse 'drop clasts' in the form of granitoid pebbles and cobbles occur in all units of siltstone and mudstone. In its thicker portions in Bombas Township, the succession reaches about 1000 m in total thickness.

The detritus comprising the sedimentary rocks reflect the local Archean bimodal granitoid-volcanic bedrock terrain. To the west and northwest are syenites, monzonites, and granodiorites, and to the north and east are mafic volcanic rocks. On the western side of the trough, the basal conglomerates have an arkosic matrix with granitoid clasts. Eastward, the conglomerates grade into dark green chlorite-rich lithic (volcanic) matrix-supported conglomerates. In the upper units, distinctive beds, lenses, and clasts of red-coloured arkosic sandstone occur interlayered with the dominantly green-coloured lithic sedimentary rocks. The proportion of red-coloured arkosic sandstone decreases in abundance from west to east, and becomes more mixed with the green-coloured lithic material eastward to suggest filling of the trough was from the west, northwest, and north, and possibly from the east as well.

Subsidence occurred during deposition in the trough by down faulting and tilting of the strata. Near the margins of the trough, the upper siltstones are juxtaposed against the basal conglomerate or against the basement Archean rock. Shearing can be observed in some of the marginal conglomerates, sandstones, siltstones, and argillites. Soft-sediment deformation can be observed as well which likely formed during the down faulting. The dips of the strata vary from 30° to 60° to <10° from the margins of the trough toward the central portions of the trough. Subsidence along the intersection of the trough and the Kirkland Lake-Larder Lake Fault Zone in Holmes and Burt Townships is reflected by the marginal faults that were parallel to, and likely continued activity along, the Kirkland Lake-Larder Lake Fault Zone. Silicification and quartz-vein development occurs in the Gowganda rocks in the trace of the Kirkland Lake-Larder Lake Fault Zone.

Two ages of diabase occur in the Kirkland Lake map sheet (not shown on Figure 1). The oldest are diabase dikes of Matachewan age which intrude all the Archean rocks. They are the most numerous in the western part of the map area and are unconformably overlain by the Gowganda Formation.

In places there are irregular discontinuous northeast-trending diabase dikes, some of which cut the Gowganda Formation. These diabases are considered to be equivalent to the Nipissing Diabase which cuts the Proterozoic rocks farther south.

Economic Geology

In the Kirkland Lake map area, the Pacaud tuffs probably represent the marginal remnants of a calc-alkalic volcanic pile farther south. Likewise, the Skead Group also represents the distal facies of a second volcanic pile farther to the southeast. Numerous tuff horizons of these 2 groups contain pyrite, and other minor sulphide mineralization, as well as graphite, and/or iron formation which remain largely unexplored for precious metals.

The Larder Lake Group which hosts the Kerr Addison Gold Deposit and numerous other smaller deposits in the Larder Lake area and the iron formation in Boston Township has numerous graphitic and carbonate sedimentary units with pyritic mineralization in the Kirkland Lake area. Many of these units, as well as numerous zones of carbonate alteration associated with quartz and quartz-carbonate veins, remain to be systematically explored for precious metals and base metals.

Some gold and base-metal mineralization occur in Holmes Township (Moore 1966). However, it was not recognized that many of the mafic volcanic rocks were Timiskaming types nor that the associated Timiskaming sedimentary rocks were so extensive (Figure 1). Gold mineralization is present in the Timiskaming rocks cut by syenite dikes and further work is needed to delineate the gold mineralization for possible gold deposits similar to those in Kirkland Lake.

Silicification and quartz-veining, which occurs in the Gowganda Formation above the trace of the Kirkland Lake-Larder Lake Fault Zone, suggests that gold-bearing fluids could have penetrated fractures in the Gowganda Formation and the underlying Archean rocks.

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No. 15 Englehart Synoptic Mapping Project

L.S. Jensen[1]

Introduction

The Englehart Synoptic mapping project represents a continuation of the stratigraphic synthesis of the Timmins-Kirkland Lake sheet. Because most of the field season focused on completing the Kirkland Lake map area (*see* Jensen, this volume), mapping of the Englehart sheet was limited to a reconnaissance of the volcanic rocks in the eastern portion of the map area.

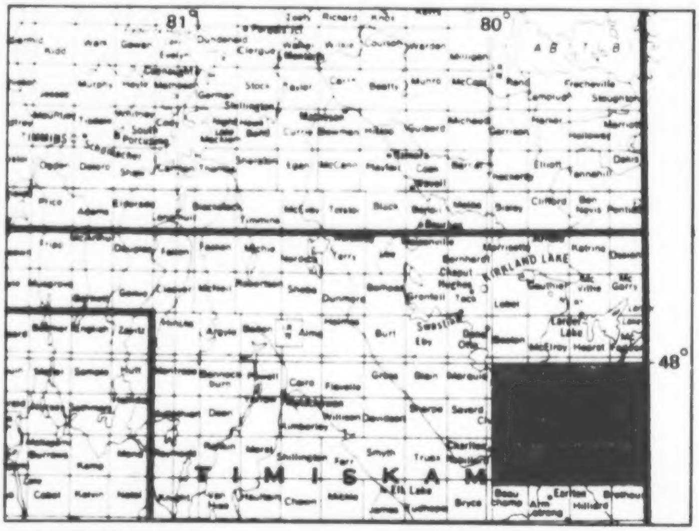
Mineral Exploration

Initial prospecting began in the 1900s during the silver boom in Cobalt and the discovery of gold in the Larder Lake area in 1906, and has continued to the present day. Some of the early exploration activity is described in geological reports on the area by the Ontario Department of Mines (Hewitt 1951; Grant 1963; Moorhouse 1944; Burrows and Hopkins 1922; Knight 1907). More recent reports are by Lovell and Ploeger (1980), Lovell (1977), and Johns (1980).

General Geology

Bedrock in the Englehart sheet consists of Early Precambrian (Archean) metavolcanics and metasediments and some mafic to ultramafic intrusions, all of which are cut by granitoid rocks ranging in composition from trondjhemite to syenite. The Archean rocks are unconformably overlain by Proterozoic rocks of the Gowganda Formation. Nipissing Diabase intrudes both the Gowganda Formation and the Archean rocks. In the southern part of the area, Paleozoic rocks of Ordovician and Silurian age unconformably overlie the Archean and Proterozoic rocks.

Many of the lower groups of Archean volcanic rocks found on the southern limb of the synclinorium in the Kirkland Lake-Larder Lake area (*see*Jensen, this volume) extend southeast to form the bedrock in the Englehart area. They include the Pacaud Tuffs, Wabewawa Group, Catherine Group, Skead Group, and Larder Lake Group. The groups together form a steeply dipping, east-facing, 18 km thick monoclinal succession east of the Round Lake



LOCATION MAP Scale: 1:1 584 000 or 1 inch to 25 miles

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[1] Geologist, Precambrian Geology Section, Ontario Geological Survey, Toronto

Batholith. Except for the Pacaud Tuffs and the Larder Lake Group, these groups of volcanic rocks can be correlated with the volcanic units in the Charlton area (Johns 1980).

Komatiitic and tholeiitic lavas and associated sedimentary rocks of the Larder Lake Group (Jensen 1980) are covered by Proterozoic rocks of the Gowganda Formation and hence are not exposed in the eastern and southern parts of the map area. A north- to northeast-trending fault zone, analogous to the Destor-Porcupine Fault Zone and the Kirkland Lake-Larder Lake Fault Zone, is thought to exist below the Proterozoic sedimentary rocks (Jensen and Langford 1983). Below the Proterozoic rocks, the Larder Lake Group is considered to be juxtaposed against granitoid rocks of the Pontiac Massif in Quebec.

Economic Geology

Several occurrences of gold are present in the Archean metavolcanics and many of these have been described in reports by Hewitt (1951), Grant (1963), Moorhouse (1944), and Lovell and Ploeger (1980). Gold is found mainly in quartz and quartz-carbonate veins in association with pyrite, chalcopyrite, molybdenite, and in places sphalerite and galena. Most of these occurrences are within the Skead Group calc-alkalic volcanic fragmental rocks. However, some occur as well in the underlying Catherine Group, Wabewawa Group, and Pacaud Tuffs.

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No. 16 Blezard Township, District of Sudbury

J.M. Martins[1]

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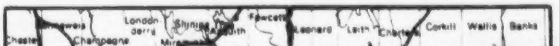
Introduction

Blezard Township is situated 3 miles north of the City of Sudbury. The southeastern corner of the township lies at Latitude 46°32'10"N and Longitude 80°56'45"W. Highway 69 traverses the centre of the township; the remainder of the area is accessible via power line access roads, company and regional roads, the Canadian National Railway right-of-way, and Whitson Lake. Mapping was carried out during the 1982 and 1983 field seasons at a scale of 1:15 840 with more detailed examinations (1:4800 scale) in selected areas.



LOCATION MAP Scale: 1:1 584 000 or 1 inch to 25 miles

Mineral Exploration

Since the discovery of the Murray Mine nickel-copper orebody in 1883, mineral exploration has continued in the area investigated, and in the Sudbury mining camp in general. No attempt is made here to summarize the assessment file information available in the Resident Geologist's Office, Ontario Ministry of Natural Resources, Sudbury, or to discuss the voluminous literature on the Sudbury nickel-copper mines.

In the map area, all of the nickel-copper mineralization occurs in the sublayer at the outer margin of the Sudbury Igneous Complex where it is in contact with older metasediments, metavolcanics, and granite (Pattison 1979). One other unit in the township, the Onaping Formation, has associated Cu-Zn-Pb-Au-Ag mineralization. On the Papineau Property, lot 3, concession V, a shaft was sunk prior to 1929 on mineralized quartz veins (Resident Geologist's Files, Ontario Ministry of Natural Resources, Sudbury). A grab sample assayed 0.22 ounce gold per ton and 0.78 ounce silver per ton. A similar deposit occurs in lot 7, concession V.

Elsewhere in the township, recorded exploration for base metals, gold, and silver took place mainly during the 1950s when a number of companies and individuals submitted diamond-drilling and geological surveys for assessment (Resident Geologist's Files, Ontario Ministry of Natural Resources, Sudbury).

General Geology

Published geological maps of the township consist for the most part of compilation maps; the most recent one is by Dressler (1983).

The rocks in the township, all of Proterozoic age, can be subdivided into 3 main groups: metavolcanics and metasediments of the Elliot Lake Group (Huronian Supergroup) intruded by the Murray Granite; the Whitewater Group; and the Sudbury Igneous Complex.

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The basal formation of the Elliot Lake Group, the Elsie Mountain Formation, which forms the footwall to the Sudbury Igneous Complex in the southeastern part of the township, comprises a sequence of metamorphosed mafic flows, much altered in the vicinity of the Igneous Complex by hornfelsing and hornblende-biotite veining. Higher in the sequence the mafic metavolcanics are massive and fine to medium grained. Dip is vertical or steeply to the south. Porphyritic and amygdaloidal units are common and pillows occur in several places. In the upper part of the sequence rhyodacite units appear. Occasional small rhyolite bodies also occur.

In the uppermost part of the Elsie Mountain Formation, thin metapelite and metasandstone beds are present. The contact with the overlying Stobie Formation is conformable and placed where the metasediments appear in appreciable quantities (greater than 15%), following the scheme of Card (1978, p.29). The Stobie Formation consists predominantly of metasediments with subordinate intercalated metavolcanics. At the base, metapelites with well developed staurolite-rich bands (now largely chlorite and quartz) are interbedded with metasandstones showing flame structures and crossbedding. The bedded units dip steeply to the south or are overturned. Strike direction is variable, in places probably due to "Sudbury brecciation". Amphibolite bodies occur throughout the Stobie Formation and likely represent mafic intrusions. Phase layering was observed in lot 2, concession I, within a large amphibolite body. In both the lower and upper part of the Stobie Formation, clean, well sorted quartzites, with very occasional pebble trains, occur. Polymictic conglomerates interbedded with arenites and wackes were seen in lot 3, concession I. Just to the east of this, in lot 2, thin, very fine grained beds represent possible ash units and are associated with mafic and intermediate flows.

The Copper Cliff Formation rhyolite overlies the Stobie Formation. In Blezard Township, rocks of the lower part of the formation are massive felsic metavolcanics which form prominent topographic highs. Flow banding is present although indistinct. Higher in the formation, flow banding is more strongly developed and individual porphyritic and fragmental flows can be distinguished. Flow thicknesses of about 10 m were noted. Some units of a more intermediate composition contain irregular pink patches of garnet. In the uppermost units of the formation some features have a sedimentary character and might represent reworked rhyolites or rhyolite tuffs.

In the extreme southeastern corner of the township, a massive fine-grained quartzite showing a different fracture pattern to the underlying Copper Cliff Formation, probably represents the basal unit of the McKim Formation.

In the south-central part of the township, the Murray Granite intrudes the Lower Huronian sequence and forms the footwall to the Sudbury Igneous Complex in this area. The rock is a massive pink quartz monzonite containing numerous xenoliths of mafic metavolcanics along its northwestern margin. It has been dated at 2200 Ma by Gibbins *et al.* (1972).

Sudbury Breccia (pseudotachylite) occurs in all rocks older than the deposition of the Whitewater Group rocks. It forms large irregularly shaped bodies and thin dikelets and contains host rock fragments and minor "exotic" fragments. The larger bodies appear to be more common in the incompetent rocks of the Elsie Mountain and Stobie Formations. In the more competent Copper Cliff rhyolite and Murray Granite, commonly only small dikes occur.

The Whitewater Group infills the basin of the Sudbury Structure. It is subdivided into 3 conformable formations, from bottom to top: the Onaping Formation, the Onwatin Formation, and the Chelmsford Formation. The origin of the Onaping Formation (volcanic breccia or meteorite fallback breccia) has been discussed by many workers. The most recent discussion is by Muir (1981). In Blezard Township the formation is well exposed, and is here subdivided according to the scheme of Peredery (1972). The Basal Breccia which overlies the granophyre, the uppermost unit of the Sudbury Igneous Complex, ranges in thickness from 50 to 200 m and consists mainly of quartz-arenite and arkose fragments in a fine recrystallized matrix. Bedding is visible in some large fragments. In lot 4, concession IV, a quartz-pebble quartzite displays sequential disintegration from large bedded blocks, down to small fragments, and finally until the more resistant quartz pebbles occur alone in the breccia matrix.

In Blezard Township, the Grey Onaping is 600 to 700 m wide, and comprises country rock fragments (granite, quartz arenite, arkose, chert, and less commonly metavolcanics) generally less than 1 m in diameter (locally blocks exceed 10 m) set in a fine-grained, grey, siliceous matrix. Variation occurs in areas where cobble-sized inclusions are set in a matrix of shards and glassy fragments. Shearing has caused elongation of fragments along strike.

The Grey Onaping passes up into the black unit which has a characteristic fine-grained carbon-rich matrix with variable amounts of rock fragments similar to, although smaller than, those in the Grey Onaping.

The intrusive rocks of the Sudbury Igneous Complex have been studied by many workers, for instance Kuo and Crocket (1979). A discontinuous marginal sublayer zone at the base of the complex hosts the Ni-Cu sulphide deposits. The sublayer consists of gabbro, norite, and country rock fragments set in an igneous quartz-dioritic matrix. This is overlain by norite, a 1500 m wide body consisting of plagioclase, hypersthene, augite, blue quartz, and micrographic intergrowth. A date of 1848 Ma has been established for the South Range norite by Krogh *et al.* (1979).

The uppermost Sudbury Complex is a 3000 m wide granophyre, the top part of which shows evidence of contamination by the basal Onaping Formation. The main mass of the granophyre consists of a pink phase (highly sheared and fractured) and a more massive phase. Granophyric intergrowth typifies both types.

The norite and granophyre are separated by an 800 m wide quartz gabbro characterized by ilmenite, magnetite, and apatite, and the lack of orthopyroxene.

Fine-grained pink and grey granites and leucogranites intrude the norite and quartz gabbro. Some intrusions are sill-like, striking parallel to the main direction of the igneous rocks and dipping 45° to 50° to the north; others are pod-like or dike-like. Granite commonly occupies linear swamps, which suggests an association with regional fracture patterns. The bodies range in width from a few millimetres to 80 m, and in length up to 1500 m. Xenoliths of norite and gabbro are common in them. Margins do not exhibit chilling, but alteration effects on the mafic rocks extend up to 2 m and produce a characteristic honeycomb weathering pattern as biotite masses are degraded.

The granites appear to be confined to the norite and quartz gabbro of the Sudbury Igneous Complex. They were noted in only 3 locations in the granophyre and only in 1 place in the underlying Huronian sequence. Late Precambrian olivine diabase dikes cut all rocks in the township.

Structural Geology

The strike of the major rock units varies from easterly in the northern half of the township to northeasterly in the southern half. A pervasive foliation parallel to the strike of the rocks exhibits a consistent dip of about 70° south.

Two major east-trending faults, the Falconbridge and Cliff Lake Faults, pass through the central part of the township. Common small-scale faulting strikes consistently at 030°. A predominant joint direction of 145° with dips varying from 82° to 90° was noted in all Sudbury Igneous Complex rocks.

Rocks of the Elliot Lake Group generally dip steeply south, but are locally overturned. Some possible folding was noted, but rotation of blocks near zones of Sudbury Breccia made this difficult to confirm. Late olivine diabase dikes generally trend 125°, but 1 dike in the southwestern quadrant of the township has a strike of 085°.

Glacial grooving and striae give a direction of ice movement through the township of 215° to 220°.

Economic Geology

Nickel-copper-precious-metal deposits associated with the sublayer occur along the lower margin of the Igneous Complex and in offset dikes within the footwall rocks. The various ore types are discussed in papers by Pattison (1979), Naldrett *et al.* (1972), and Souch *et al.* (1969). Ore minerals include pyrrhotite, pentlandite, and chalcopyrite with pyrite, magnetite, and ilmenite.

The Onaping Formation has potential for copper-lead-zinc mineralization. In Creighton and Fairbank Townships, the contact of the Onaping Formation with the overlying Onwatin Formation has proved to be economically interesting and has in the past supported a producing mine.

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No. 17 Howland Area: Haliburton, Peterborough, and Victoria Counties

R.M. Easton[1]

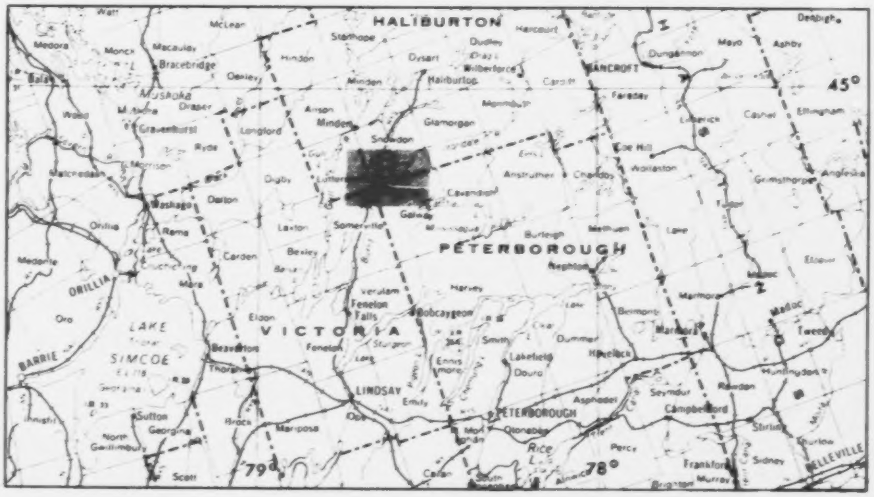
Introduction

The Howland map area is located 140 km northeast of the City of Toronto and includes parts of Galway, Lutterworth, Snowdon, and Somerville Townships. The map area covers about 270 km^2 and is bounded by Longitudes 78°30′W and 78°45′W, and by Latitudes 44°45′N and 44°52′30″N. The northwest corner of the map area lies 5 km south of the Town of Minden, and access is provided by Highways 121 and 503 which traverse the central part of the map area, as well as Highway 35 which parallels the western boundary of the map area. Township roads, 2 abandoned Canadian National Railway right-of-ways, cottage roads, logging roads, and snowmobile trails provide good access to all of the map area.

Mineral Exploration

The history of mineral exploration and production in the Howland area dates back to the 1880s when the Howland, Imperial, and Victoria Mines (Figure 1) extracted massive magnetite ore (combined total of 2000 tons) from deposits situated along the Irondale, Bancroft, and Ottawa railway. In addition, stone and marble were also extracted along this rail route in the vicinity of Irondale at the turn of the century.

Recorded exploration within the area has been very limited (Assessment Files Research Office, Ontario Geological Survey, Toronto (AFRO)) despite considerable exploration work just east of the map area (Bright 1980). Recorded exploration has searched for either uranium or lead-zinc mineralization. Exploration for uranium in the map area peaked during the uranium boom of the 1950s, and saw a minor resurgence during the late 1960s to early 1970s, for instance by Belra Explorations Limited, and during the late 1970s in the vicinity of Crystal Lake. St. Joseph Explorations Limited examined several localities in the marbles of the map area for lead-zinc mineralization in the mid-to-late 1970s. Exploration was concentrated in the Salerno and Bow Lake areas (Figure 1), and uncovered a sizeable, but at present subeconomic, zinc deposit (AFRO). Sulpetro Minerals Limited (previously St. Joseph Explorations Limited, name changed 1981) has


HALIBURTON
PETERBOROUGH
VICTORIA
LAKE SIMCOE
45°
79°
78°
Bracebridge
Muskoka
Gravenhurst
Minden
Haliburton
Snowdon
Somerville
Galway
Lutterworth
Cavendish
Glamorgan
Dysart
Stanhope
Bancroft
Faraday
Coe Hill
Wollaston
Chandos
Anstruther
Burleigh
Methuen
Harvey
Bobcaygeon
Fenelon Falls
Verulam
Fenelon
Lindsay
Orillia
Barrie
Washago
Rama
Carden
Dalton
Digby
Laxton
Bexley
Eldon
Beaverton
Thorah
Mara
Oro
Medonte
Smith
Dummer
Lakefield
Douro
Belmont
Marmora
Havelock
Peterborough
Seymour
Asphodel
Rawdon
Tweed
Madoc
Huntingdon
Belleville
Sidney
Frankford
Stirling
Rice Lake
Percy
Grimsthorpe
Anglesea
Elzevir
Cashel
Ellingham
Ashby
Mayo
Dungannon
Limerick
Denbigh
Harcourt
Dudley
Wilberforce
Monmouth
Hindon
Oakley
Macaulay
Monck
Medora
McLean
Draper
Longford
Ryde
Morrison
Matchedash
Anson
Emily
Ennismore
Mariposa
Brock
Georgina
Sutton
North Gwillimbury
Scott
Cartwright
Manvers
Cavan
Otonabee
Ops
Tudor
Lake

LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

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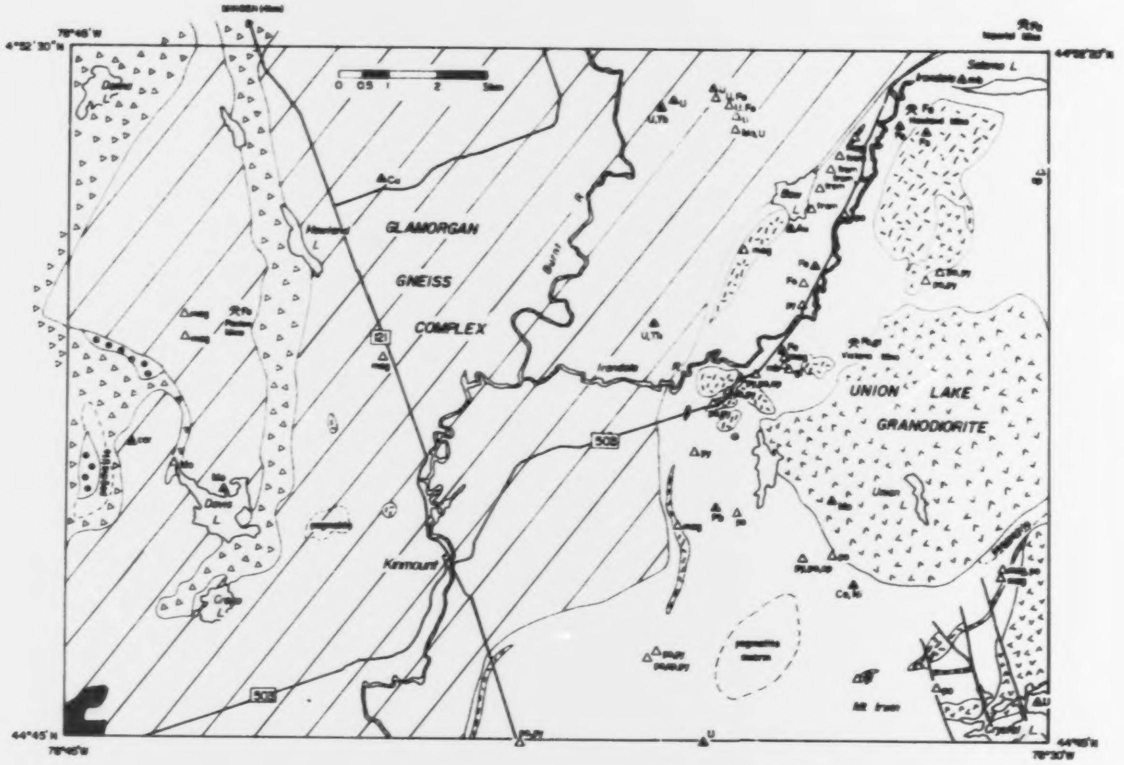
78°45'W
4°52'30"N
44°52'30"N
0 0.5 1 2 3km
Howland L
GLAMORGAN
GNEISS
COMPLEX
Burnt R.
Irondale R.
Salerno L.
121
503
UNION LAKE
GRANODIORITE
Union L.
Davis L.
Kinmount
Mt. Irwin
Crystal L.
44°45'N
78°45'W
44°45'N
78°30'W
U
U,Th
Cu
mag
Fe
py
po
Mo
cor
Co,Ni

KEY

■ Paleozoic rocks

PRECAMBRIAN ROCKS

Plutonic rocks

- ▨ granodiorite, granite
- ▨ gabbro, diorite, syenite
- △ Denna Lake Structural Complex
- ☐ Grenville Supergroup
- ● 'Older' Supracrustal rocks
- ▨ Glamorgan Gneiss Complex

— fault

minerals

Au	gold
Co	cobalt
cor	corundum
cp	chalcopyrite
Cu	copper
Fe	iron
gf	graphite
mag	magnetite
mb	marble
Mo	molybdenum
Ni	nickel
Pb	lead
po	pyrrhotite
py	pyrite
sp	sphalerite
Th	thorium
trem	tremolite
U	uranium

Figure 1. Simplified geologic map of the Howland area, showing the location of mineral showings. See text for descriptions of major rock units. Filled triangles represent showings previously reported by the Ontario Geological Survey (Satterly 1943; Hewitt and Satterly 1957; Ontario Geological Survey 1983a, 1983b). Open triangles represent showings and pits discovered by 1983 field party members.

continued the work to the present. Geological Data Inventory Folios (GDIF) are now available for Galway (Ontario Geological Survey 1983a) and Snowdon (Ontario Geological Survey 1983b) Townships.

In addition, field party personnel located several pits and trenches in the area for which no information is on record in the Assessment Files Research Office, Ontario Geological Survey, Toronto. The location of these pits and the mineralization is shown in Figure 1.

General Geology

A simplified geologic map of the Howland area is presented in Figure 1. The area is underlain mainly by Precambrian rocks. Flat-lying Ordovician limestone of the Gull River Formation, and minor greenish grey, coarse, calcareous arkose, and red and green shales of the Shadow Lake Formation at the base, cover the Precambrian succession in the southwestern corner of the map area. The Paleozoic strata have been described by Liberty (1952).

Precambrian rocks in the Howland area are of Proterozoic age, and form part of the Central Metasedimentary Belt (Wynne-Edwards 1972) of the Grenville Province; however, rocks in the western and northwestern part of the map area lie only 10 km southwest of the boundary between the Central Metasedimentary Belt and the Central Gneiss Belt (Wynne-Edwards 1972).

The Precambrian rocks may be divided into 5 main groups (Figure 1). In order of interpreted decreasing age these are:

1. the Glamorgan Gneiss Complex which underlies the central half of the map area
2. supracrustal rocks which may be older than the Grenville Supergroup and are present only in the western part of the map area
3. supracrustal rocks of the Grenville Supergroup
4. a structural complex, named here the Denna Lake Structural Complex, as defined by article 37 of the Code of Stratigraphic Nomenclature (North American Commission on Stratigraphic Nomenclature (NASCN) 1983), in the western and northwestern part of the map area, mainly consisting of disrupted Grenville Supergroup strata
5. younger, foliated and unfoliated, plutonic rocks which intrude the supracrustals and the Glamorgan Gneiss Complex

Glamorgan Gneiss Complex

The Glamorgan Gneiss Complex can be subdivided on the basis of lithology into 5 mappable units. These units correspond to lithodemic units (roughly equivalent to formations) as described in the revised Code of Stratigraphic Nomenclature (NASCN 1983) and are defined below in order of interpreted decreasing age.

The Kinmount Lithodeme consists of homogeneous, grey to dark grey, medium-grained, hornblende ± biotite tonalite to quartz diorite gneiss, with millimetre- to centimetre-scale pods and layers of syenite and syenogranite pegmatite which are parallel to the gneissosity and are characterized by potassium feldspar augen.

The Kendrick Creek Lithodeme consists of homogeneous, grey, medium-grained, plagioclase-quartz-biotite ± hornblende ± potassium feldspar quartz diorite to granodiorite gneiss. Near contacts with the Kinmount Lithodeme it contains millimetre- to centimetre-scale layers of syenodiorite pegmatite parallel to gneissosity, but layers are spaced on a centimetre to metre scale, and are less abundant than in the Kinmount Lithodeme.

The Crego Lake Lithodeme consists of homogeneous monzogranite to syenogranite gneiss, commonly containing 5 to 10% magnetite. In the northern and western part of the Glamorgan Gneiss, this lithodeme is characterized by quartz stretched in the plane of the foliation.

The Davis Lake Lithodeme is found along the shore and to the northwest of Davis Lake. The lithodeme is heterogeneous, consisting of syenogranitic gneiss similar to that forming the Crego Lake Lithodeme, but containing rafts and house-sized blocks of quartz-plagioclase-biotite ± hornblende gneiss with centimetre- to decimetre-scale layering, possibly relict bedding; amphibolite; gabbro; and granodiorite and tonalite gneiss.

The Howland Lithodeme is a heterogeneous gneiss characterized by 1 to 2 m scale interlayering of tonalite, quartz diorite, granodiorite, and syenogranite gneiss and amphibolite in roughly equal proportions.

The 5 lithodemes define a stratigraphic sequence within the Glamorgan Gneiss Complex. Type locations and geological position of the lithodemes will be described in an Ontario Geological Survey report in preparation.

Older Supracrustal Rocks

Due west and northwest of Davies Lake are 2 outcrop areas (Figure 1) of distinctive supracrustal rocks found nowhere else in the map area. The western exposure consists of migmatitic, fine- to medium-grained, grey, quartzo-feldspathic biotite gneiss with a granodiorite mobilizate which has an earlier fabric folded prior to the development of the regional foliation. In contrast, Grenville Supergroup siliceous clastic metasediments in the immediate vicinity consist of metawacke and metasiltstone with distinct bedding, and no mobilization phase or earlier fabric. The northwestern exposure is similar to the western exposure, except here the rocks are a pink-weathering, decimetre to metre scale layered quartzo-feldspathic gneiss, possibly meta-arkose with a minor monzogranite mobilizate. Both supracrustal outcrops show evidence of a migmatization event not recorded in adjacent Grenville Supergroup strata, and hence may be older.

Grenville Supergroup

The bulk of the southeastern part of the map area is underlain by medium-grained calcite marble (± phlogopite ± graphite ± tourmaline) with interlayered clastic siliceous metasediments, mainly metawacke and metasiltstones.

In the Crystal Lake area, a west-plunging antiform exposes a siliceous clastic sequence, consisting, from oldest to youngest, of at least 10 to 20 m of quartzarenite, overlain by 5 m of marble and calc-silicate rock, overlain by 20 to 30 m of arkosic arenite, overlain by 30 to 50 m of interbedded arenaceous metasediments and amphibole-rich rocks, possibly volcanic in origin. On the north limb of the antiform, syenite was intruded along the meta-arenite/metavolcanic contact. Also on the north limb, quartz- and monzogranite-pebble conglomerate is interbedded with quartzarenite. The clastic sequence at Crystal Lake probably underlies the main carbonate succession in the map area.

A possibly lithocorrelative stratigraphic sequence to that at Crystal Lake is present in the Bow-Salerno Lakes area (Figure 1). The sequence here dips and faces southeast. The base of the sequence consists of dolomitic marble (now tremolite) and plagioclase-quartz-biotite-hornblende gneiss, overlain by quartzarenite and arkosic arenite, in turn overlain by plagioclase-hornblende-biotite gneiss, possibly derived from a volcanic terrain. The top of the sequence consists of calcitic marbles interlayered on the metre scale with siliceous clastic metasediments.

Denna Lake Structural Complex

The western and northwestern part of the map area is underlain by a heterogeneous assemblage of tectonically disrupted strata (Figure 1), named here the Denna Lake Structural Complex. Three main lithologies are present:

1. a marble breccia, consisting of a coarse-grained, white to pink calcite matrix with rounded inclusions of siliceous metasediments, calc-silicate rocks, and layered marble
2. rusty weathering siliceous metasediments
3. a variety of granitoid rocks ranging from monzogranite to syenite in composition and showing varying degrees of disruption

House-size and larger blocks of both the siliceous metasediments and the granitoid rocks are also present in this zone.

Near Buller Lake, 3 km due west of the west-central edge of the map area, coarse-grained dolomitic marble (now mainly tremolite) within the Denna Lake Structural Complex contains continuous millimetre- to centimetre-scale silica segregations. These segregations resemble structures in low grade Grenville Supergroup marble that have been interpreted to be algal mats.

Plutonic Rocks

The plutonic rocks may be subdivided into 4 groups:

1. an older mafic group (gabbro, minor diorite and quartz diorite)
2. a syenite-diorite group (syenite, magnetite-diorite and leucodiorite
3. a granodiorite to syenogranite group
4. a younger syenite-granite group (syenogranite and syenite pegmatite)

Metamorphism

Metamorphic grade in the area increases toward the northwest from lower amphibolite grade near Crystal Lake to upper amphibolite grade near Denna Lake. The lowest grade pelitic rocks in the Crystal Lake area may contain andalusite, but sillimanite-muscovite assemblages are more common. Metamorphic grade increases toward the Glamorgan Complex, as indicated by increasing grain size and the appearance of tremolite ± diopside assemblages in the marble. Marbles in the Denna Lake Structural Zone preserve diopside-tremolite-scapolite assemblages.

Structural Geology

In general, all units strike north to northeast and have shallow dips to the southeast. All, except the younger granite group, have a penetrative lineation-schistosity (L-S) metamorphic fabric with a southeast plunging lineation. Two older fold sets are present in both the Grenville Supergroup and the Glamorgan Complex, which do not fold the L-S fabric. A late, east-trending, subhorizontal warping about a shallow-plunging axis folds the penetrative L-S fabric in both the Grenville Supergroup and Glamorgan Complex rocks. The intensity of cataclasis and strain in the rocks increases from southeast to northwest across the map area, coincident with increasing metamorphic grade.

Marbles within the Grenville Supergroup along the southern margin of the Glamorgan Complex commonly display horizontal to subhorizontal millimetre- to centimetre-wide mylonite zones which are continuous over a strike length of 10s to 100s of metres.

Economic Geology

Base Metals

Dolomitic marble in lots 31 and 32, concession III of Snowdon Township contains visible sphalerite, and has been optioned and drilled by St. Joseph Explorations Limited and Sulpetro Minerals Limited (AFRO). It is similar in setting to the Balmat zinc mine in New York State. The only other sizable occurrence of dolomitic marble in the area lies within 1 km of the southern margin of the Glamorgan Gneiss Complex, and is a potential zone for zinc mineralization. Lead mineralization has not been reported within the map area, although St. Joseph Explorations Limited found anomalous values for Pb in a geochemical survey near Bow Lake (AFRO), and several showings are present in Galway Township adjacent to the southern margin of the map area (Ontario Geological Survey 1983a). Pyrite, pyrrhotite ± chalcopyrite are common in siliceous metasediments throughout the map area, in particular in the contact zones around mafic and granodiorite plutons. Some of the largest occurrences are shown in Figure 1. Much of the sulphide mineralization in the region is near magnetite-bearing skarns, especially along the Irondale River, and could be extracted along with the magnetite. Possible metavolcanics in the Crystal Lake area may also be a favourable horizon for base metals, particularly near the margin of the Crystal Lake diorite.

Iron Deposits

Four types of iron deposits occur in the map area:

1. massive magnetite in carbonate skarns
2. magnetite in diorite to syenite intrusions adjacent to the southeastern margin of the Glamorgan Gneiss
3. magnetite in the Crego Lake Lithodeme, as well as cross-cutting syenite and syenogranite pegmatite veins
4. a lithified regolith developed over pyritic carbonates

Massive magnetite occurs in carbonate skarns near the margin of several diorite and gabbroic plutons along the Irondale River between Furnace Falls and Salerno Lake (Figure 1). The Howland, Victoria, and Imperial Mines belong to this type of mineralization. Several pits containing massive magnetite are also present in the area. Although individual deposits may be subeconomic, the close proximity of the deposits may allow for extraction of ore from the deposits as a group.

Magnetite is common in the diorite-syenite bodies along the southeastern margin of the Glamorgan Gneiss, and locally accounts for up to 50% of the rock. The more sizable concentrations observed by field party personnel are located on Figure 1. This class of deposits has been previously unrecorded.

Magnetite is also common in syenogranite of the Crego Lake Lithodeme, and cross-cutting syenite and syenogranite pegmatite veins throughout the Glamorgan Gneiss. Concentrations of coarse-grained magnetite constitute 10 to 20% of the host rock in places. In the late 1800s (Adams and Barlow 1910), the Paxton Mine (Figure 1) extracted magnetite ore from gneiss of the Crego Lake Lithodeme near a contact with marble tectonic breccia. In some areas, the magnetite-bearing veins are also uraniferous (for example, lots 18,19, concession VI, Snowdon Township).

A lithified regolith of Recent or Pleistocene age is developed over pyritic carbonates of the Grenville Supergroup along Highway 503, 6 km southwest of Irondale (lot 19, concession II, Snowdon Township). The deposit occurs over a strike length of about 250 m, and may continue farther along-strike beneath cover. The deposit is overlain by good quality glaciofluvial sand and gravel deposits, and good quality, white, pure, dolomite marble is present in the vicinity of the iron deposit. Together, these 3 commodities may make an economic prospect.

Other Metallic and Precious Minerals

Uranium and thorium mineralization previously recorded in the area is shown in Figure 1. All of these areas have appreciable scintillometer anomalies (up to 10 times background) and lie within regional gamma-ray spectrometric anomalies (Ontario Geological Survey 1978). Uranium and thorium mineralization in the area is confined to syenogranitic to syenite pegmatite veins cutting rocks of both the Grenville Supergroup and the Glamorgan Gneiss Complex. Locally these veins may contain up to 15% magnetite in association with uranium and thorium mineralization.

Molybdenite is present throughout the map area (Figure 1). Disseminated molybdenite crystals are present in marble breccia on the northeastern tip of Davis Lake, in Glamorgan Gneisses on the north shore of Davis Lake, and in syenogranite pegmatites north of Bow Lake. Molybdenite has also been reported in the Denna Lake Structural Complex 5 km southwest of the map area (AFRO). Belra Exploration Limited also reported molybdenite in the Union Lake granodiorite body (lot 17, concession XVI, Galway Township; AFRO).

Graphite is present in many of the marbles in the area, accounting for 1 to 3% of the rock. Local concentrations of 5 to 20% graphite were observed by field party personnel and are located on Figure 1. The showing north of Mount Irwin (lot 15, concession XIII, Galway Township) may be the source of the mineralized float reported in GDIF 56 (Ontario Geological Survey 1983a).

Minor gold is present in a quartz vein on the southwestern shore of Bow Lake (lot 19, concession III, Snowdon Township; AFRO). Similar quartz veins extend along the southern margin of the Glamorgan Gneiss for a distance of 2 km south of Bow Lake.

Non-Metallic Mineral Resources

Several stone and marble quarries were operated along the Irondale, Bancroft, and Ottawa railway near the turn of the century, but these quarries have since been abandoned and are now overgrown. Pure, white, dolomitic marble is present in several areas (Figure 1) and may be of commercial value. Of interest to mineralogists is the presence of tremolite-dolomite marble on the southeastern shore of Bow Lake. Good quality sand and gravel deposits occur along the Burnt and Irondale River systems. Of concern to developers is the presence of karst features, such as sinkholes in several areas of the map area, most notably the Mount Irwin-Crystal Lake area.

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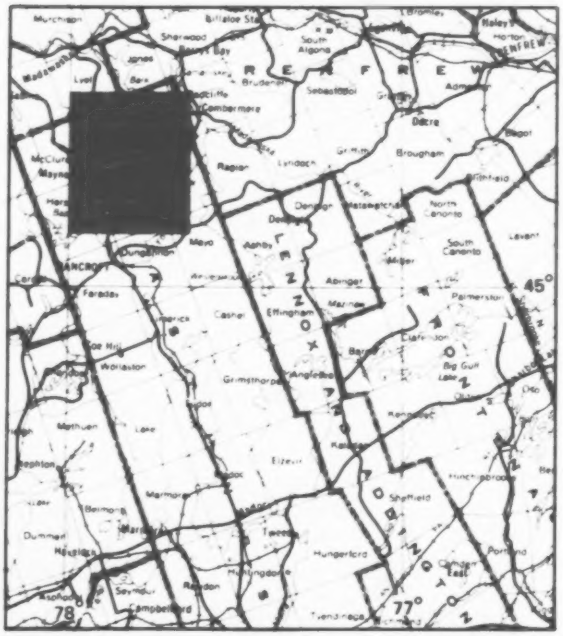
No. 18 Northern Bancroft-Southern Barry's Bay Area, Hastings County and Nipissing District

Robert H. Thivierge[1]

Introduction

The study area is located about 170 km west of Ottawa and 220 km northeast of Toronto, and covers about 972 km^2. It is bounded by Latitudes 45°07′N and 45°25′N, and by Longitudes 77°38′W and 78°00′W, occupying the Monteagle (NTS 31 F/4NW) and Wicklow (NTS 31 F/5SW) map sheets, as well as parts of adjacent sheets to the north, south, and east. The map area includes all or most of Wicklow, Bangor, Herschel, Monteagle, and Carlow Townships, and parts of McClure, Lyell, Jones, Radcliffe, Dungannon, and Mayo Townships. Access is mainly by Highway 62, which traverses the area between the Towns of Bancroft to the southwest, and Barry's Bay to the northeast. Access is also provided by Highway 517 in the eastern, Highways 127 and 523 in the west-central and northwestern, and the Musclow-Greenview road in the south-central parts of the area, as well as by numerous secondary roads.

The Bancroft area was first investigated on a regional scale by Adams and Barlow (1910). Detailed geological mapping of Radcliffe, Monteagle, and Carlow Townships was performed by Hewitt (1954, 1955), and of Dungannon and Mayo Townships by Hewitt and James (1955). Recent reconnaissance mapping by Lumbers (1982) extends into the northern and northeastern margins of the study area. The current study is an extrapolation of work undertaken by Breaks and Thivierge (1982) and Thivierge (1982), focusing on the structure, metamorphism, and basement-cover relationships of the Grenville Supergroup around its northern margin. It will lead to a better understanding of the geology and the mineralization environments of the area.


Murchison
Bufaloe St.
Sherwood
Barry's Bay
South Algona
Madawaska
Jones
Lyell
Brudenell
R E N F R E W
RENFREW
Radcliffe
Combermere
Sebastopol
Admaston
Haley's
Horton
Dacre
Bagot
Raglan
Lyndoch
Griffith
Brougham
McClure
Mayo
Blithfield
Denbigh
Matawatchan
North Canonto
South Canonto
Levant
Dungannon
BANCROFT
Ashby
Abinger
Faraday
Palmerston
45°
Effingham
Cashel
Limerick
Clarendon
Barrie
Big Gull Lake
Wollaston
Grimsthorpe
Anglesea
Oso
Methuen
Lake
Kennebec
Elzevir
Hinchinbrooke
Marmora
Belmont
Sheffield
Dummer
Madoc
Tweed
Hungerford
Portland
Camden East
Huntingdon
Seymour
Rawdon
Campbellford
Tyendinaga
Richmond
78°
77°

LOCATION MAP

Scale: 1:1 584 000
or 1 inch to 25 miles

Mineral Exploration

Mineral prospecting in the area dates back to the late 1890s when corundum was discovered in the Burgess area of Carlow Township by W.F. Ferrier (Geological Survey of Canada). Production of corundum at the Craigmont Mine, just east of the map boundary in Raglan Township, ranged from 1900 to 1913, 1919 to 1921, and 1944 to 1946. In northern Carlow Township several small corundum deposits were worked before 1916. Nepheline deposits in the York River area of Dungannon Township were exploited around 1905, and again between 1937 and 1942. The York River nepheline syenite gneisses and associated pegmatites just south of the map area produced over 13 000 tons of nepheline ore from the Goulding-Keena, Morrison, and Davis Quarries (Storey and Vos 1981), with minor quantities of corundum. Chemical analyses indicate an alumina content somewhat low and erratic for production of raw alumina, but the ore could be enhanced to produce suitable material (Storey and Vos 1981).

Trenching for feldspar was performed in northeast-trending, commonly zoned, granite pegmatite dikes concentrated in the Hybla area, Monteagle Township, during the 1920s and intermittently after the mid-1930s until the early 1950s. Fourteen small mines were operated within a 3.2 km radius of the MacDonald Mine (Hewitt 1955).

Graphite was a major product of the area from the Tonkin-Dupont/National Graphite Deposit in lots 23 and 24, concession XIII, Monteagle Township, near the community of Graphite. A total of 792.5 tons of refined graphite was mined, mainly for use as artillery lubricant, between 1913 and 1916. Although nonproductive since 1917, the deposit saw renewed exploration and drilling in 1952 by McKenzie Red Lake Gold Mines Limited, and in 1962 by National Graphite Limited. In 1981, J.R. Lill performed VLF-EM and magnetometer surveys on the deposit, which outlined some conductive and anomalous magnetic zones around the old workings.

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In the 1950s, Bancroft and its neighbouring areas were explored for uranium, however, no significant prospects were opened in the map area. Several claims were staked at the Thomas and Dubblestein uranium Occurrences on Balsam Lake in Bangor Township (Masson and Gordon 1981).

A magnetic survey followed by diamond drilling in 1949 and 1950 by L. Moyd of Bancroft outlined small magnetite bodies within a differentiated metagabbro near Fraser Lake in Carlow Township (Hewitt 1955).

General Geology and Structural Subdivision of the Area

The map area lies entirely within the Haliburton-Hastings-Madawaska Highlands (Hewitt 1962), and straddles a complex transitional zone between Grenville Supergroup supracrustal rocks and associated metaplutonic bodies of Segment IVa of the Central Metasedimentary Belt (Wynne-Edwards 1972) in the southeastern half of the area. This zone underlies "grey gneiss" and migmatites of the Ontario Gneiss Segment in the northwestern half of the area. Segment IVa is primarily defined by Wynne-Edwards (1972) in the Glamorgan and Cardiff areas west of Bancroft where northernmost Grenville Supergroup rocks of Hewitt's highlands region, including important suites of alkalic gneiss, envelop domal masses of a remobilized "basement" rock.

The area is herein subdivided into 2 major domains, the Segment IVa of Central Metasedimentary Belt and the Ontario Gneiss Segment, which in turn are subdivided into 6 subdomains. The subdivision into subdomains is similar to the tectonic subdivisions described by Davidson *et al.* (1982) for lithotectonic domains in the western Ontario Gneiss Segment.

Segment IVa of the Central Metasedimentary Belt

The Boulter Subdomain occurs in the southeastern portion of the map area and is characterized by biotite schist, arkosic paragneiss, calcitic marble, and layers of metavolcanic amphibolite, including pillowed metabasalt at Rowland Hill. These supracrustal rocks enwrap the Mallard Lake metagabbro and Boulter metatrondhjemite plutons, which dominate this portion of the subdomain. The lithological association of pillowed metabasalt-metagabbro-metatrondhjemite is quite distinct from other subdomains.

The York River Zone separates the Boulter Subdomain from the Monteagle Subdomain and follows the York River in an arcuate north- to east-northeast-trending pattern around the Boulter Subdomain. Along the river it features mylonitic marble and recrystallized marble tectonic breccias, as well as comminution, fracturing, and slickensiding in other rocks. It marks the first northward occurrence of a suite of nepheline-bearing metasyenites in a discontinuous belt from Egan Chute to Conroy Rapids. Generally rocks of the York River Zone are similar to those in the Monteagle Subdomain. Megascopic structural trends along, and adjacent to, the York River Zone suggest that it is a resolving dextral shear.

The Monteagle Subdomain occupies the south-central and east-central map area and appears to be continuous into the York River Zone. It is characterized by skarns, generally rusty calcsilicate rock and calcareous meta-arkose, impure calcitic marble, and marble tectonic breccia with some scapolite gneiss, biotite schist, siliceous paragneiss, and quartzite. Small local units enriched in graphite are most common in the northern region around Graphite and Greenview. Metamorphic and metasomatic syenitic rocks, as well as hybrid feldspathic gneisses, are widespread and intermixed with the metasediments. Many syenites and leucogranites are gradational into each other and bear clinopyroxene.

Undeformed curviplanar pink granite pegmatite dikes, trending northeast and generally dipping steeply northwest to subvertical, occur in many areas and are loosely referred to as the late Hybla dikes. One very large dike extends for a few kilometres along Hemlock Ridge in northeastern Wicklow Township (Breaks and Thivierge 1982).

The Herschel Subdomain occurs in the southwestern portion of the map area between Baptiste Lake and the Town of Maynooth. It consists mainly of variably migmatized heterogeneous, medium-grained, tonalitic to granodioritic gneiss with amphibolitic pods and lenses. Large areas are dominated by syntectonic, medium- to coarse-grained, granite mobilizate-rich migmatite, commonly with accessory allanite. These rocks core a tight fold closure with an east- to east-southeast-trending axial trace and a southeastward plunge into Monteagle Township.

Ontario Gneiss Segment

The Ontario Gneiss Segment covers the northern half of the map area, and is largely equivalent to the Radcliffe Hybrid Gneiss of Hewitt (1954) and to rocks of the "Algonquin Batholith" of Lumbers (1982). As within the Herschel Subdomain, heterogeneous rocks of intermediate composition and migmatites abound.

The Papineau Lake Straight Zone constitutes the northern boundary for Grenville Supergroup rocks in the area, and trends broadly northeasterly and dips about 20° to the southeast. It is 2 to 9 km wide, runs from Maynooth through Papineau Lake to Combermere, and appears to be continuous both eastward and westward (Breaks and Thivierge in preparation). In this zone, nebulitic and gneissose hornblende-biotite migmatites, with units carrying abundant isolated or clustered feldspar augen, are common and grade into gneissic tectonic breccias. These breccias contain tonalitic to amphibolitic gneiss fragments and locally exotic metagabbroic or gabbroic meta-anorthosite fragments. Many fragments display a discordant internal foliation and/or gneissosity which is tightly isoclinally folded and truncated by the enveloping gneissosity. Most lithologies just described correspond to Lumbers' (1982) basal coarse clastic (arkosic) sequence of the Grenville Supergroup. Lumbers considers them to reflect a major unconformity. They bear a strong resemblance to rocks of tectonite zones (Davidson *et al.* 1982) in the western Ontario Gneiss Segment, which bound and separate allochthonous crustal segments.

The Interior Algonquin Domain occurs north of the Papineau Lake Zone. It consists of heterogeneous, grey, migmatitic, trondhjemitic, and tonalitic gneisses, and minor biotite paragneiss and gneissic granitoid rocks. It is characterized by megascopic, southeast-plunging, open to tight folds which are spaced 5 to 10 km apart and abut against the Papineau Lake Zone.

Metamorphism

The rocks of the area were subjected to upper amphibolite facies, locally to hypersthene granulite facies, of regional metamorphism. No occurrence of hypersthene is known within or southeast of the York River Zone. Within the Ontario Gneiss Segment it occurs locally in coronitic or massive amphibolite, and in anatectic pods in the Little Papineau Lake metadiorite Stock (Breaks and Thivierge in preparation). Within the Monteagle Subdomain it occurs in amphibolites as well as in coarse-grained, pink metasyenite in a region roughly between McAlpine Corners and Monteagle Valley. The highest metamorphic conditions in the area are represented by hypersthene-garnet-gedrite-cordierite-sapphirine gneiss from the Hoare Lake area at the northern edge of the Papineau Lake Straight Zone (Miller 1983). Peak metamorphic conditions are estimated to have been near the kyanite-sillimanite boundary (temperature = 770°C, pressure = 8.5 kbar) prior to diminishment of load pressure (Breaks and Thivierge in preparation). Coarse-grained kyanite has also been reported coexisting with sillimanite in metapelite about 3 km north of Foster Rapids (York River) in Carlow Township (Hewitt 1955).

Carbonate rocks of the Monteagle Subdomain, and at least parts of the York River Zone, are generally calcitic and contain >10 to 15% silicate minerals. Most appear to belong to the diopside-scapolite zone of metamorphism. Rare pelitic rocks of the area bear garnet, sillimanite, and biotite.

Economic Geology

Little base- and precious-metal mineralization is known to occur in the map area. Metavolcanic amphibolites in Monteagle Township locally host disseminated pyrite and pyrrhotite, form massive lenses less than 1 m in length, and occur locally in hybrid leucocratic syenitic gneiss associated with amphibolites just north of Quirk Lake and 0.8 km southwest of Monteagle Valley.

The Mallard Lake metagabbro does not host any known sulphide deposits, but is similar to the Raglan Hills metagabbro, nearby to the east, which contains 4 copper-nickel deposits. These consist of disseminated to massive pyrrhotite, and chalcopyrite with minor pyrite and pentlandite, and are associated with small pyroxenitic bodies (Carter *et al.* 1980).

In northern Monteagle Township, local stratabound marble-hosted disseminated graphite occurs in volumes of up to 15% and generally less than 5%. The graphite mineralized layers are discontinuous and commonly occur associated with biotite meta-arkose and calcsilicate rock with or without pyrrhotite-bearing siliceous paragneiss.

Syenitic gneisses and associated pegmatites of the northern Carlow and York River areas host interesting, locally rich corundum- and nepheline-bearing zones. Many of these deposits were mined in the past and warrant further investigation.

Uranium mineralization is found in 2 main areas. Within the Interior Algonquin Domain at Balsam Lake in Bangor Township, pyrochlore is present within a zoned granite pegmatite mass (Dubblestein Occurrence) which holds uranium mineral analyses of 6.36 and 8.63% U_3O_8. Radioactive mineralization, in a small hematized area within granite pegmatite, also located at Balsam Lake (Thomas Occurrence), assayed 540 parts per million U_3O_8 and 1.7% thorium (Masson and Gordon 1981). At numerous localities in the Hybla area, Monteagle Township, radioactive and rare-element minerals are common within zoned northeast-trending granite pegmatites which were generally mined for feldspar in the first half of this century. Notable is the MacDonald Mine in lots 18 and 19, concession VII, which produced 35 048 tons of feldspar between 1919 and 1935. The radioactive minerals allanite, betafite, uranothorite, cyrtolite, and ellsworthite are reported from here, and combinations of these, as well as pyrochlore, are found in other pegmatite dikes of the area (Masson and Gordon 1981).

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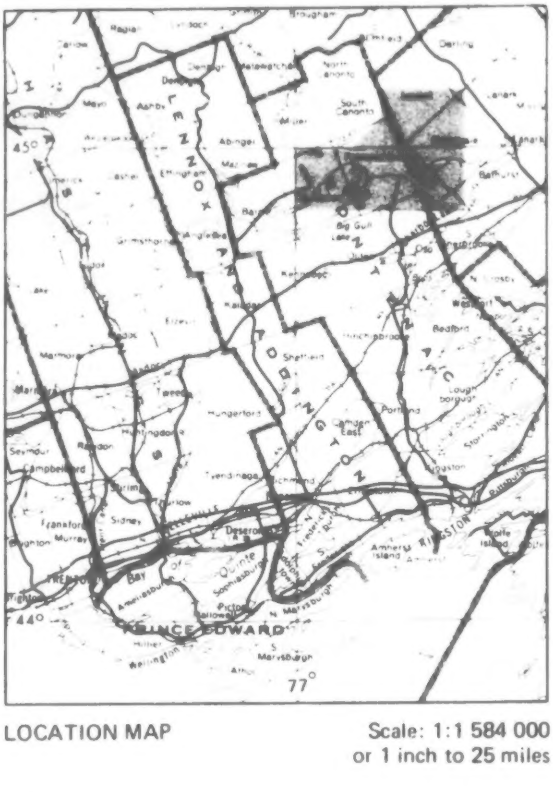
No. 19 Sunday Lake Area and Ardoch-Dalhousie Lake-Lavant Area, Frontenac and Lanark Counties

Liba Pauk[1]

Introduction

The aim of the present synoptic project is to obtain a better understanding of the lithostratigraphy and structure of areas previously mapped in detail by the author (Pauk 1981a, 1982b, 1983) and, in turn, to obtain a better understanding of the origins and controls of mineralization environments. A small area outside of the 1981-1982 map areas, the Sunday Lake area, was mapped in detail. It provided structural and stratigraphic information critical for an interpretation of the geology of the area as a whole and for an understanding of the geology of the Flinton Group of the Grenville Supergroup.

The area is located approximately 100 km southwest of the City of Ottawa, and is bounded by Latitudes 44°52'30''N and 45°07'30''N, and Longitudes 76°30'W and 77°00'W. It is accessible by Highways 506 and 509 and many secondary county and cottage roads.



LOCATION MAP

Scale: 1:1 584 000
or 1 inch to 25 miles

Mineral Exploration

Exploration for gold, uranium, iron, base metals, and industrial minerals in the area dates back to the 1880s. The author previously presented summaries on the mineral exploration activities in the area (Pauk 1981b, 1982a, 1982c).

General Geology

The map area lies within the Hastings Basin of the Central Metasedimentary Belt (Wynne-Edwards 1972) of the Grenville Province. It is underlain by Middle Proterozoic supracrustal rocks of the Grenville Supergroup and by a variety of Middle Proterozoic syntectonic to late tectonic intrusive rocks. The oldest rocks are metavolcanics, and carbonate and clastic metasediments, which are correlated by the author with the Hermon and Mayo Groups defined by Lumbers (1967) in the Madoc area. The above sequence was intruded by syntectonic felsic intrusive rocks of the Northbrook Batholith and the Addington Complex, and by the syntectonic Lavant Gabbro Complex and the Dalhousie Amphibolite Complex. Clastic and carbonate sedimentary rocks of the Flinton Group (Moore and Thompson 1972, 1980) were unconformably deposited on the Hermon and Mayo Groups rocks, and on the older felsic intrusive rocks (Moore and Thompson 1980, Psutka 1976). All of these rocks were subjected to low to upper amphibolite facies metamorphism and to polyphase deformation. Late tectonic felsic intrusions (Barbers Lake Intrusion, Elphin Intrusion) and a large number of pegmatite dikes and sills occur in the area.

Structural Geology

The map area is subdivided by a major northeasterly trending fault, the Robertson Lake Shear Zone (Smith 1958), into a strongly deformed western structural zone and a less deformed eastern structural zone.

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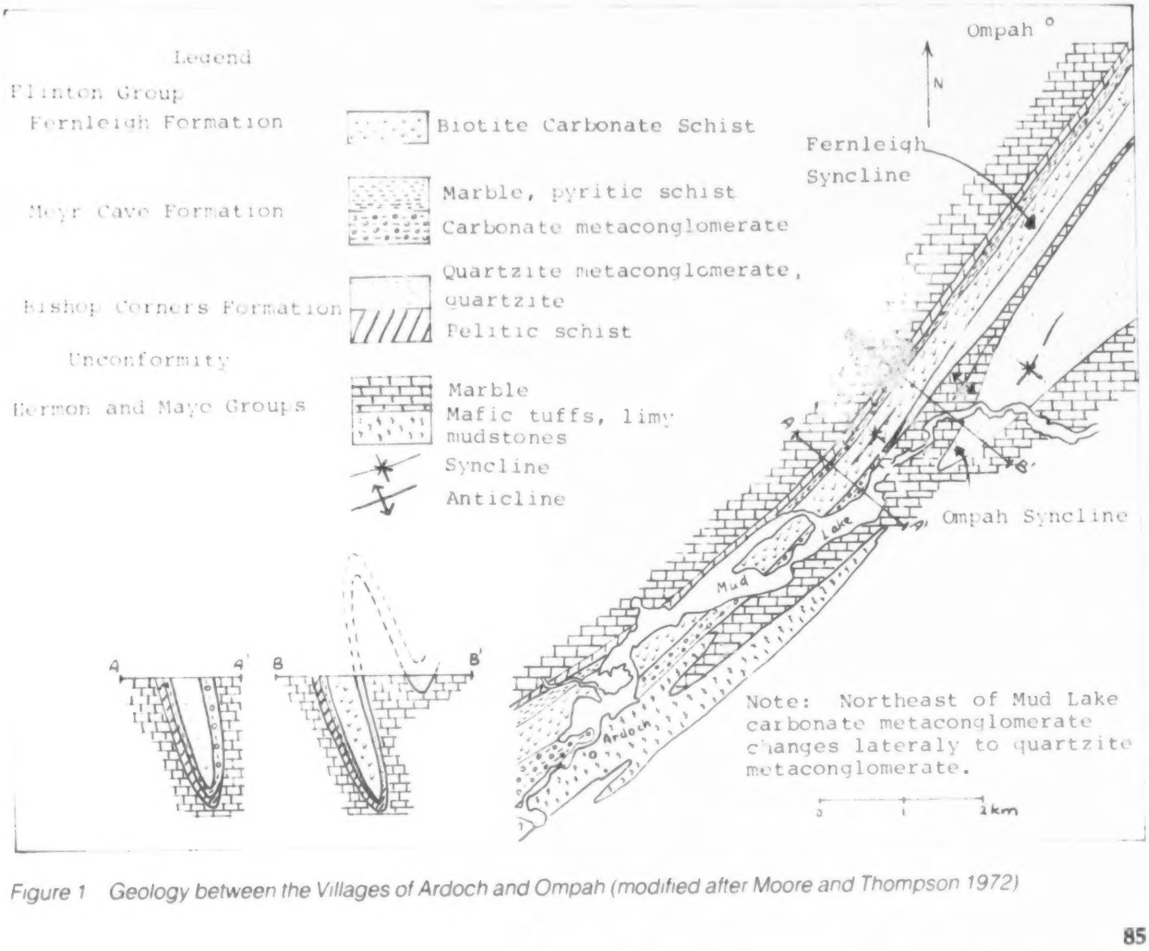
The western structural zone is underlain largely by supracrustal rocks and by syntectonic felsic intrusive rocks which have been subjected to at least 2 phases of post-Flinton Group deformation. These phases are represented by a series of northeasterly striking regional synforms and antiforms and by small scale folds. The first phase of deformation (D_1) produced isoclinal and recumbent folds and northeast-trending stratiform foliations. The second phase of deformation, coaxial with D_1, produced large scale open fold structures. Preliminary maps of the area (Pauk 1981a, 1982b, 1983) show all major fold and fault patterns.

Flinton Group

One objective of the present project was to better document the areal distribution of the rocks of the Flinton Group, and to investigate these rocks in greater detail.

Within the map area, the Flinton Group rocks occur in the Ompah and Fernleigh Synclines (Moore and Thompson 1972; Pauk 1982b), and also form narrow discontinuous layers and narrow belts that are infolded with rocks of the Hermon and Mayo Groups along the hinge and southern and northern limbs of the Cross Lake Antiform (Pauk 1982a).

Figure 1 shows the geology of the Flinton Group in the Fernleigh Syncline between the Villages of Ompah and Ardoch. The group is made up of pelitic schist, quartzite, and metaconglomerate of the Bishop Corners Formation; marble, schist, and marble conglomerate of the Myer Cave Formation; and biotite-carbonate schist of the Fernleigh Formation (Moore and Thompson 1972, Pauk 1982b, 1983). The syncline persists along strike for some 35 km, enters the area of investigation from the southwest, and the present mapping has shown that it ends about 12 km northeast of the Village of Ardoch. East of


Legend
Flinton Group
Fernleigh Formation
Biotite Carbonate Schist
Meyr Cave Formation
Marble, pyritic schist
Carbonate metaconglomerate
Bishop Corners Formation
Quartzite metaconglomerate, quartzite
Pelitic schist
Unconformity
Hermon and Mayo Groups
Marble
Mafic tuffs, limy mudstones
Syncline
Anticline
Ompah
N
Fernleigh Syncline
Ompah Syncline
Mud Lake
Ardoch
A
A'
B
B'
0
1
2 km

Note: Northeast of Mud Lake carbonate metaconglomerate changes lateraly to quartzite metaconglomerate.

Figure 1 Geology between the Villages of Ardoch and Ompah (modified after Moore and Thompson 1972)

the Village of Ompah, conglomerate of the Bishop Corners Formation becomes infolded with biotite carbonate schists of the uppermost Fernleigh Formation. Some 3 km farther to the northeast, near Sunday Lake, the Fernleigh Formation is attenuated and only quartz-pebble conglomerate interlayered with quartzofeldspathic biotite gneisses of the Bishop Corners Formation is exposed. Some 3 km northeast of Sunday Lake, however, the Fernleigh Formation, as well as marble and graphitic, pyritic schist of the Myer Cave Formation, reappear. The Bishops Corners Formation here also contains meta-arkose representing a lateral facies change. Both lateral and vertical facies changes are common throughout the Flinton Group (Moore and Thompson 1980).

South of the Village of Ompah, the Ompah Syncline, consisting largely of quartz-pebble and polymictic metaconglomerate, quartzite, and calcareous quartzite, of the Bishop Corners Formation, lies near the Fernleigh Syncline (Figure 1) and is separated from it by an anticline of Mayo Group marbles. Here the core of the Ompah Syncline is made up of calcareous quartzite, and, towards the northeast, of hornblende-biotite and hornblende gneisses and schists. Along the northern limb of the syncline, a band of calcitic and dolomitic marble, which is up to 300 m wide and up to 6 km long, contains well preserved stromatolites. East of the Village of Ompah is the "Sunday Lake Synform" which is composed of fine-grained, laminated to massive, hornblende-biotite and hornblende schists and gneisses. These rocks stratigraphically overlie Flinton Group metasediments and either represent a post-Flinton volcanic sequence (Smith 1967) or a clastic-pelitic sedimentary sequence derived from volcanic rocks. The source for these sedimentary rocks probably lies 6 km northeast of the Sunday Lake Synform where intermediate to mafic metavolcanics, correlated by the author with the Hermon Group, occur.

Close to the Sunday Lake Synform, the Bishop Corners Formation along the southern limb of the Ompah Syncline is thin and terminates about 700 m northeast of Sunday Lake.

Economic Geology

Summaries on the economic geology of the Ardoch-Dalhousie Lake and Lavant areas were published by Pauk (1981b, 1982a, 1982c). During the present investigations the author observed 2 mineral occurrences in the vicinity of Sunday Lake.

The first occurrence lies at the southern limb of the Sunday Lake Synform where stratiform layers and lenses of massive pyrite and pyrrhotite, up to 70 cm thick and up to at least 2 m long and probably much longer, occur intermittently over a strike length of about 1.5 km. The sulphide mineralization lies along the contact of hornblende-biotite schists with clastic siliceous and pelitic metasediments. Two shallow pits and minor surface stripping are the only indications of any exploration activities here.

The second mineralized occurrence is a zone of narrow (3 to 30 cm wide) quartz veins containing stringers and seams of galena, sphalerite, and minor disseminated chalcopyrite and pyrite. It occurs within partly granitized layers of quartzofeldspathic muscovite gneiss and quartzite 300 m north of Sunday Lake. The zone is approximately 13 m wide and about 500 m long.

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Engineering and Terrain Geology Programs

Summary of Activities, Engineering and Terrain Geology Section, 1983

Owen L. White[1]

Introduction

The number of field parties placed in the field by the Engineering and Terrain Geology Section was reduced to 6 (from 10 the previous year), largely because of the phasing out of several externally funded programs. In contrast, the field activities of the Hydrocarbon Energy Resources Program (HERP), funded by the Board of Industrial Leadership and Development (BILD), were at their peak when, in addition to other field duties, almost 8000 m of stratigraphic drilling were completed under the control of the Section Staff. Aggregate Assessment activities continued with studies in Grey County, the Sault Ste. Marie area, and the Espanola area.

P.J. Barnett completed the mapping of the Long Point and Port Burwell areas through detailed studies and measurements of the bluff sections along the Lake Erie shoreline. Such studies provided an excellent 3-dimensional view of the Port Stanley and Wentworth tills, as well as the Paris and Galt Moraines which mark the westernmost limit of the advance of ice out of the Erie basin.

The mapping of the surficial deposits of Algonquin Provincial Park was completed in 1983 with 2 field parties under the leadership of R.S. Geddes and M.J. Ford. The southwestern portion of the Park, which included the Algonquin and Kawagama map sheets, was mapped by the Geddes field party, while the Ford field party completed the mapping of the Lake Lavieille area (started in 1982) and continued into the Opeongo Lake and Whitney areas.

Geddes' mapping in the southwestern portion of Algonquin Park found the till cover was less extensive in the southwest than in the northwest, although it was thicker in the areas around Fletcher Lake and Little Kinnisis Lake. Tills range from lodgement tills to melt-out and flow till types. Ice-contact deposits were also less extensive in the southwest than in the northwest, but outwash deposits were extensive throughout the area investigated and provided most of the potentially useful deposits of sand and gravel. The more obviously useful aggregate deposits lie outside of the Park boundaries. Glaciolacustrine deposits (associated with glacial Lake Algonquin), consisting of varved silts and clays, are found near Lake of Bays. Other fine-grained deposits found in several localities, such as around Tom Thomson Lake, appear to be associated with a different proglacial lake. Several significant deposits and landforms attributed to the glacial history of the area, accessible through public camping areas and areas traversed by major canoe routes, have been identified as being of possible interest to the Algonquin Park interpretative program.

In mapping the southeastern portion of the Park, M.J. Ford found more extensive till coverage than encountered in mapping the northeastern area the previous year. The till is a compact, silty sand to sandy silt material with up to 10% clasts included. Glaciofluvial deposits are also widespread, but generally have high contents of sand and oversized boulders. Major deposits occur near White Partridge Lake and Lake Traverse, and along Highway 127. Deposits of lacustrine origin are few and far between, but peat and other organic deposits are extensive in several areas. Despite the handicap of excessive sand and boulder contents, the glaciofluvial deposits should be adequate for all Park requirements of sand and gravel.

U.J. Vagners mapped the Quaternary geology of the Matheson and Lightning River map areas as part of the current multi-disciplinary investigation by the Ontario Geological Survey of the Black River-Matheson area. A major objective of this project was to establish a geological framework for future detailed drift studies, which are expected to assist exploration in the area. The till of the area has a silty sand texture. Striations and other directional features indicate a regional flow of the ice from the northwest. During earlier phases of the glaciation, ice flow was from the northeast.

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Ice-contact deposits, especially eskers and kames, are common throughout the map area, with the northern end of the major Munro Esker being located within the map area. The most widespread materials are the silts and clays deposited in glacial Lakes Barlow and Ojibway. Other lacustrine deposits and associated shoreline features and beach deposits occur throughout the area. Dune sand deposits also occur in several townships in the area.

Sand and gravel pits have been opened at several localities in the area, and especially in the Watabeag Esker near Matheson and along Highway 101. Sand and gravel resources in the area should be adequate to meet future demands for some time. The widespread lacustrine clay deposits do not appear to be of commercial value as they are reported to have a high lime content and produce bricks which do not stand up to weathering.

D.J. Russell, in continuing his work on the Paleozoic outliers, obtained access to core recovered from the Lake Timiskaming area which is now stored in Halifax, Nova Scotia. The core has been relogged following Russell's recent work in the area. Further investigations were done on the outliers in Renfrew County and revisions completed to ensure compatability with recent work completed farther down the Ottawa Valley by Williams and Rae (this volume). As this project approaches its conclusion, the Paleozoic outliers are in the process of being viewed, as a whole, perhaps for the first time, not only between the various outliers themselves but also in relationship to the Paleozoic deposits of southern Ontario.

D.A. Williams and A. Rae concluded the mapping of the Paleozoic rocks of the Ottawa-St. Lawrence Lowland by first-time mapping in the Arnprior area, reviewing previous mapping in the rest of the project area, and visiting adjacent areas to ensure regional consistency. The Preliminary Maps and Open File Report should be available within the next few months.

Paleozoic rocks up to 1130 m thick occur within the project area and are overlain by a variable thickness of glacial deposits which, although very thin in the vicinity of the Ottawa River, thicken to the south and west.

The basal clastic unit of the Paleozoic sequence (Covey Hill Formation) is overlain by quartz sandstone of the Nepean Formation, which provides a source of silica sand for the glass and foundry industries and which, in the past, was a source of building stone for many buildings in Ottawa. The completion of the mapping program should assist the private sector in exploring for locations in which this stone could be exploited. The March, Oxford, Rockcliffe, Gull River, Bobcaygeon, and Lindsay Formations, which overlie in succession the Nepean Formation, have had wide use as a source of crushed stone. Dolostone with interbedded sandstone is the major lithologic type in the older formations, with limestone dominant in the Gull River and younger formations. The occurrence of shale in the Lindsay Formation makes this unit less desirable as a source of crushed stone. The younger Billings to Queenston Formations have high shale contents and are not suitable as sources of crushed stone, although the Queenston shale is quarried for use in brick making.

The eastern part of the project area is heavily faulted with vertical displacements along some faults of up to 900 m. Numerous fault junctions, each involving a large number of faults, have been mapped.

The Aggregate Resources Inventory Program continued with field and office work concentrated in 3 areas: Grey County, the Sault Ste. Marie area, and the Espanola area.

The 3 townships investigated in the northern part of Grey County have much smaller reserves of sand and gravel than do their sister townships in southern Grey County, but their land surface is underlain by dolostone of the Amabel and Guelph Formations which can supply major quantities of good quality crushed stone and, in the case of the Guelph Formation, high purity dolomitic lime.

In the Sault Ste. Marie area, the major sand and gravel resources are related to the beach deposits and deltas formed by and in glacial Lake Algonquin, and are located to the north of the city against the Precambrian bedrock uplands of the Gros Cap Batholith. Further supplies of good quality gravel are to be found along the valleys of the upper Root River system and the Goulais River. Sand and gravel are also obtained by draglining material from the St. Mary's River. The large resources of sand and gravel available in the Sault Ste. Marie area will preclude the necessity of opening quarries for crushed stone for some years to come.

In the Espanola area, 2 areas of outwash deposits have been identified as sources for development of aggregate supplies. Both areas, one near Nairn Centre and the other along the Spanish River, are already well in use. In Baldwin Township, ice-contact deposits of variable and irregular content and quality provide useful sources of crushable gravel.

The Hydrocarbon Energy Resources Program includes the evaluation of the peat, oil shale, and lignite resources of the Province. In the Autumn of 1982, the peat inventory was launched under the supervision of J.L. Riley with the investigation of 4 areas (Hearst, Armstrong, Pembroke, and Peterborough, totaling 35 000 km^2) by private sector companies. Each deposit had its own geological environment which led to a variety of peat types and conditions to be investigated. In addition, brief studies were undertaken in conjunction with the Ontario Centre for Remote Sensing (OCRS) to evaluate remote sensing techniques and to compare traditional survey methods with techniques based on satellite imagery.

The 1982 inventory and analytical program delineated 127 000 000 m^3 of humified peat (over 40 000 000 tonnes) with an average calorific value of 4380 calories/gram and an average moisture content of almost 80%. Surficial peat in the same areas was calculated at 51 000 000 m^3 (17 830 000 tonnes).

Experiences from the 1982 field program were used to modify the plans for the 1983 program. Steps were taken to ensure a more standardized approach to the field and laboratory investigations and report presentation. More use will be made of imagery obtained from the OCRS. At the time of writing, 7 sites (*see* Riley, this volume) are under investigation by 7 different companies, 3 of which were involved in the 1982 program.

M.D. Johnson extended the Oil Shale Assessment Project by the investigation of the Devonian Marcellus and Kettle Point Formations in southwestern Ontario and by some additional work on the Upper Ordovician Collingwood shale beds.

During the Fall of 1982 and Winter of 1983, 25 shallow holes (less than 125 m) were drilled into the Devonian formations; 925 m of core were collected and all holes were geophysically logged. Another hole was drilled into the Collingwood shales to recover 8.5 cm diameter core to provide samples for further testing. In addition to the shallow holes, 9 deep holes were also drilled—all but 1 terminating in the Precambrian basement. Core, totaling 5100 m, was recovered and is expected to provide a basis for stratigraphic control in studying the depositional environment of the deposits in general and the oil shales in particular. Samples from all holes have been sent for organic geochemical analysis and the results are expected shortly.

P.G. Telford and D.W. Sawicki have reported on the lignite reconnaissance drilling program in the Moose River Basin; 7 holes were drilled during the early months of 1983 in an area north of the Missinaibi River and about 60 km northwest of Onakawana. The operation was managed for the Ontario Geological Survey by Watts, Griffis and McOuat Limited, and involved over 850 m of drilling. Core was recovered wherever possible and 770 m of geophysical logging was completed. Lignite seams of 5 to 6 m thickness were encountered in 2 holes but at depths of 73 to 75 m. Numerous thinner seams were encountered in 1 other hole. Additional drilling will be undertaken in the western part of the Moose River Basin during the Winter of 1983/1984.

No. 20 Quaternary Geology and Stratigraphy of the Long Point-Port Burwell Area, Elgin County and the Regional Municipality of Haldimand-Norfolk

P.J. Barnett[1]

Introduction

Studies on the Quaternary geology and stratigraphy of the Long Point-Port Burwell areas commenced in 1982 (Barnett 1982) and were continued during this past summer. Surface mapping is completed and preliminary maps for both 1:50 000 National Topographic Series map areas have been submitted for publication (Barnett in press; Barnett and Zilans 1983).

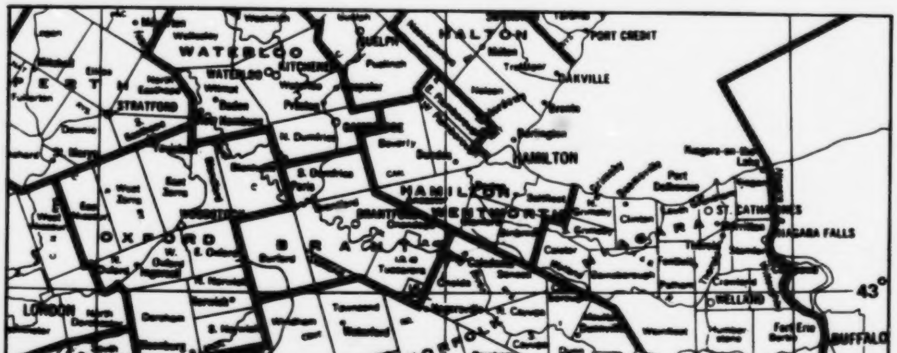
Emphasis during this past summer's field work was placed on stratigraphy and on documentation of sediment types present in this area. The Lake Erie shorebluffs and the many inland exposures along creeks and rivers provided an excellent opportunity to view the sediments deposited when the continental glaciers were last active in this part of Ontario. Both lateral and vertical changes were studied and sediment associations were noted.

General Geology

The general geology, physiography, and economic geology of the map area has been presented previously (Barnett 1982). In summary, the sediments present in the map area record several oscillations of the continental ice margin into large proglacial lakes during the general period of ice marginal retreat in the latter part of the Port Bruce Stadial and the Mackinaw Interstadial.

The lake bluffs between Port Bruce and Port Dover contain an overlapping sequence of 3 layers of Port Stanley Till separated by deltaic bottomset sands and glaciolacustrine silts and clays. These sediments were deposited during oscillations of the continental ice margin in a large proglacial lake during the latter part of the Port Bruce Stadial.

East of Port Burwell to the Sand Hills, the sediments are predominantly glaciolacustrine in origin and generally become coarser textured upward from clays and silts to fine- and medium-grained sands. They represent a re-


WATERLOO
KITCHENER
GUELPH
HALTON
PORT CREDIT
OAKVILLE
PERTH
STRATFORD
HAMILTON
HAMILTON-WENTWORTH
OXFORD
BRANT
ST. CATHARINES
NIAGARA FALLS
WELLAND
LONDON
HALDIMAND-NORFOLK
Port Dover
BUFFALO
ST. THOMAS
Aylmer
Port Stanley
43°
79°

LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

gional shallowing of a large proglacial lake which occupied the western portion of the Erie basin and record the recession of the glacier during the Mackinaw Interstadial.

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Between Jacksonburg and Erie View, a younger till, the Wentworth Till, is exposed in the lake bluffs. This till was deposited by a readvance of the last continental glacier in this area. The lake bluff sections provide a cross-section through the Paris and Galt Moraines which mark the westernmost extent of this ice advance. These moraines continue beneath the lake as the Norfolk Moraine (Sly and Lewis 1972).

The bluffs east of Erie View record the retreat from this advance. The younger Port Huron Stadial advance may be recorded in the bluffs east of Turkey Point by the change in glaciolacustrine sediments from sands up into silty clays containing ice-rafted debris. This sequence may have occurred in response to the rise in water level in the Erie basin to the Lake Whittlesey level during the Port Huron Stadial. The subsequent lowering of the water levels in the Erie basin is recorded in the coarsening upward sequence of silts to sands, above the silty clay unit.

Detailed descriptions of the sediment types present in the area will be contained in the geological report on the Long Point-Port Burwell area which is presently being prepared.

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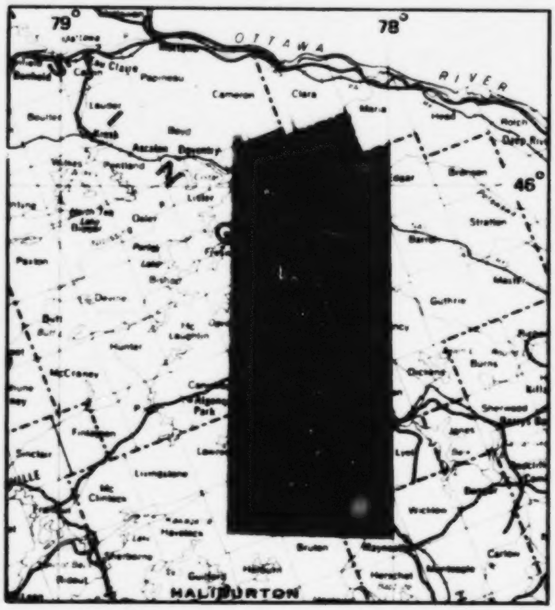
No. 21 Quaternary Geology of the Central Algonquin Park Area

M.J. Ford[1]

Introduction

This study is part of a multi-year program of surficial geological mapping within Algonquin Provinical Park. The program was initiated at the request of the Regional Parks Co-ordinator, Algonquin Region office, Ontario Ministry of Natural Resources, Huntsville, and is partly supported by Regional funding. Emphasis was placed on mapping Quaternary sediments and landforms and on determining the Quaternary geological history for use in the park's interpretive program, as well as locating potential aggregate sources for road construction and maintenance within the park.

The study area includes the Lake Lavieille (31 E/16), Opeongo Lake (31 E/9), and Whitney (31 E/8) map areas and part of the Brent (31 L/1) map area. Those parts of the Opeongo Lake and Whitney map areas lying outside the park were also mapped. Mapping in the Brent and Lake Lavieille areas was started in 1982 (Ford 1982). During the 1982 field season, the adjacent northwestern and northeastern parts of the park were mapped by Geddes and McClenaghan (1983) and Ford and Lall (1983) respectively. Geddes mapped the adjoining Algonquin (31 E/10) and Kawagama Lake (31 E/7) map areas during 1983. Geddes' work is reported separately in this volume. The area was part of the regional physiographic study of Chapman (1975) as well as the engineering terrain mapping of Gartner and VanDine (1980) and Mollard (1980a, 1980b). Access to the area is provided by forestry roads, and by power boat and canoe on lakes and rivers.



LOCATION MAP

Scale: 1:1 584 000
or 1 inch to 25 miles

Bedrock Geology

The study area lies within the Ontario Gneiss Segment of the Grenville Structural Province of the Canadian Shield (Wynne-Edwards 1972). The rocks of the area are Early to Middle Proterozoic in age, except for minor carbonate rocks of Ordovician age in the Brent area. Detailed lithologic maps are available only for the northernmost part of the area (Lumbers 1976).

Most of the area is underlain by a series of strongly banded quartzofeldspathic gneisses interlayered with biotite-hornblende gneiss, pelitic and semipelitic gneisses, and more rarely, calc-silicate gneiss. These rocks generally display pronounced flattening. In places, the rocks are migmatitic with up to 20% leucocratic neosome. Small intermediate and mafic intrusions are present in parts of the area, cross-cutting the gneisses. An unfoliated medium- to very coarse-grained hornblende gabbro is exposed along Highway 60 near Costello Lake. Davidson and Morgan (1980) noted the presence of a deformed body of gabbroic anorthosite and metaplutonic quartzofeldspathic gneiss in the southwestern part of the Whitney map area. Granitic, in places allanite bearing, pegmatite dikes up to 1.5 m wide are common and intrude the older Precambrian rocks. The larger dikes usually display well developed zoning.

In the northeastern part of the area, the most abundant rocks are felsic metaplutonic rocks, predominantly of quartz monzonite composition. Biotite and amphibole are the principal mafic minerals. Lumbers (1982) assigned similar rocks in the adjoining Achray area to the "Algonquin Batholith".

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Structural and topographic observations suggest that the banded gneiss sequence defines a large synformal structure which plunges to the southeast. The trace of the axial plane passes approximately through Big Crow, Proulx, Opeongo, Brewer, and McKenzie Lakes. A rectilinear pattern of prominent lineaments occurs in the western limb of the synform. Here the dominant south-southeasterly lineaments parallel the strike of the compositional banding in the gneisses. Those of the other set appear to be shear zones with limited lateral displacement. Strike parallel lineaments are also prominent in the eastern limb. Southeasterly striking faults of the Ottawa-Bonnechère Graben occur mainly in the northern part of the area.

Metamorphic grade is high. Lumbers (1982) stated that middle to upper almandine amphibolite facies of regional metamorphism prevails in the adjoining areas to the east. Davidson *et al.* (1979) reported several occurrences of mineral assemblages indicative of the granulite facies along Highway 60.

Physiography

The map area is part of the Algonquin Highlands and the physiography is largely controlled by bedrock structure. Over much of the region, the topography is rugged and local relief reaches as much as 150 m. In the northern part of the area, the course of the Petawawa River is controlled by faults of the Ottawa-Bonnechère Graben. Farther south, most of the lakes and streams are controlled by lineaments. Opeongo Lake, the largest lake in the park, lies within the hinge zone of the large synform and its shape is determined by this structure.

Drainage over most of the Lake Lavieille map area is north into the Petawawa River. In the most northerly part of the park, drainage is via northerly flowing streams which empty into the Ottawa River. The Madawaska system drains most of the rest of the study area, though a small area southeast of White Partridge Lake is part of the Bonnechère River drainage. The Petawawa, Bonnechère, and Madawaska Rivers are all easterly flowing tributaries of the Ottawa River.

Quaternary Geology

The principal direction of ice flow during the Late Wisconsinan was southward and varied locally from about 175° azimuth to 210° azimuth. During the 1983 field season, crossing striae were found at only 3 sites, 2 of which were north of Whitney along Highway 60 and displayed the prevalent southerly striae, cross-cutting westerly striations and crescentic scars. At the third site, several kilometres west of the village of Madawaska on Highway 60, 2 sets of striae average 190° azimuth and 140° azimuth, but did not display a consistent age relationship.

The oldest Quaternary sediment recognized in the area is a silty sand to sandy silt till. The matrix varies from massive to distinctly fissile and commonly contains thin stringers and lenses of very fine sand. It is usually compact and clast content ranges from 2 to 10%, with an average of about 5%. Unoxidized till is generally grey to olive grey. In some exposures, the till displays weak stratification, in some cases marked by differences in clast content and matrix texture. A sand to silty sand facies, with up to 50% angular cobbles and boulders, commonly overlies the compact till. It varies in thickness from 0.4 m to more than 1.5 m, but averages less than 1 m.

Glaciofluvial deposits are widespread throughout the area, occurring as outwash, kames, kame terraces, and eskers. Deposits of ice-contact stratified drift are common but are not nearly as extensive as those mapped by Geddes and McClenaghan (1983) in the northwestern part of the park. Most notable are the morainic ridges and kames present in the Hailstorm Creek area. Eskers within the area tend to be larger and longer than those in the Achray map area (Ford and Lall 1983), but are generally topographically controlled. Complexes of intersecting eskerine ridges are common, especially in the eastern part of the Opeongo Lake map area.

Like present-day streams, glacial meltwater drainage was largely structurally controlled, with flow mainly to the south and southeast. There is a major outwash deposit south of White Partridge Lake that extends south into the area of McKaskill and Shirley Lakes and links up with glaciofluvial deposits along the fault-controlled Bonnechère River valley. There are also significant outwash deposits near Lake Traverse, between Lake Lavieille and Opeongo Lake, northeast of Big Crow Lake, and along Highway 127. These deposits contain variable proportions of horizontally stratified sand and gravel and range from poorly sorted to very well sorted. Many sections are capped by as much as 2 m of massive, coarse gravel. The presence of thick glaciofluvial deposits around the margins of many present-day lakes suggests that these basins were occupied by remnant ice during deglaciation.

Only 2 occurrences of fine-grained sediments of possible lacustrine or glaciolacustrine origin were found. One site is in an area of gravelly outwash along Highway 127, 11 km south of the junction with Highway 60. The deposit consists of silty, very fine sand, silt, and minor clay overlain by poorly sorted gravel. The other occurrence is at the east end of the Lake of Two Rivers where there is silty, very fine sand grading down to dense, laminated clay, clayey silt, and minor very fine sand. Neither of these deposits appear to be mappable, but further investigation is required to assess their significance.

Throughout the area, there are deposits of peat and muck in numerous swamps and bogs. Extensive organic deposits are present near McKaskill Lake and along Hailstorm and Costello Creeks in the Opeongo Lake map area and along sections of the Crow River and Old Camp Creek in the Lake Lavieille map area. Recent alluvial deposits are found on the flood plains of many modern streams and consist of silt and fine sand along with organic material and minor gravel.

Sand and Gravel Resources

The abundant glaciofluvial deposits should meet the aggregate requirements of the area. Many of the outwash deposits tend to be sandy, such as those in the area of Lake St. Peter, but usually contain local gravelly facies. Excessive amounts of oversized material may be a problem in some deposits. The high water table conditions observed in many existing pits during the previous field season (Ford and Lall 1983) do not appear to be as prevalent in the present study area. One area where this is a problem is in the gravelly outwash along the McKenzie Lake road in the Whitney map area. Individual areas of interest will require further investigation to properly evaluate coarse aggregate potential.

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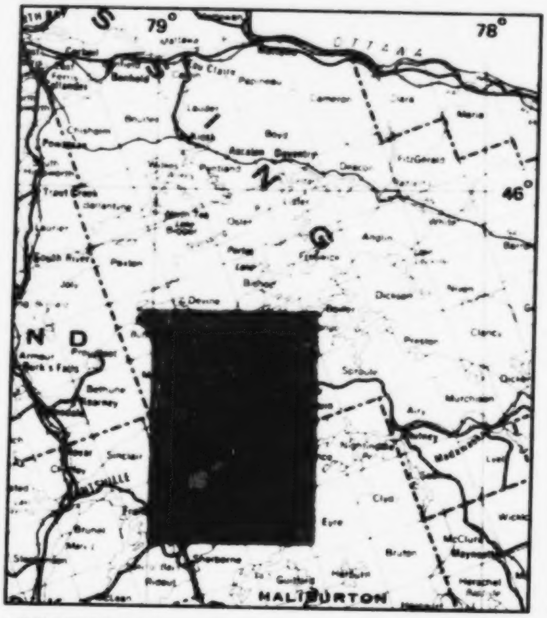
No. 22 Quaternary Geology of the Southwestern Part of Algonquin Park and the Kawagama Lake Area

R.S. Geddes[1]

Introduction

This study is part of a multi-year program designed to describe and map the surficial geology of Algonquin Park and the surrounding area. The program was initiated at the request of the Regional Parks Co-ordinator, Algonquin Region office, Ontario Ministry of Natural Resources, Huntsville. It is supported in part by Regional funding. Emphasis was placed on determining the Quaternary history, and materials which could be used in the Park's interpretive program, together with an assessment of aggregate resource potential within the Park and the area nearby. The results of the work undertaken the previous year are provided by Ford and Lall (1983) and Geddes and McClenaghan (1983).



LOCATION MAP

Scale: 1:584 000
or 1 inch to 25 miles

The area mapped was the southwestern portion of Algonquin Park, including all of the Algonquin map sheet (31 E/10), part of the Kawagama Lake sheet (31 E/7), and a small portion of the Burk's Falls sheet (31 E/11). In addition, the remaining portion of the Kawagama Lake map sheet outside the park was mapped. The total area extends from Latitudes 45°15'N to 45°45'N, and from Longitudes 79°00'W to 78°30'W. M.J. Ford mapped the adjoining area to the east during 1983 (Ford, this volume). The study area is included on engineering terrain geology maps by Mollard (1980a, 1980b, 1980c).

Much of the Kawagama Lake map sheet and a portion of the Algonquin sheet is accessible by highways and bush trails. Most of the access within Algonquin Park itself was via the extensive and well established canoe route systems and via 2 major hiking trails. Detailed studies were undertaken along these routes and supplemented by air photo interpretation.

Physiography

The map area is located within the Algonquin Highlands. Its highest part (to 560 m above sea level) strikes through the middle of the map area in a wide northwesterly direction. The slope to the southwest is rapid, where elevation drops to 330 m above sea level in the Lake of Bays area. The central portion of the map area defines a major drainage divide, with the Oxtongue and East Rivers flowing west and southwest, the Petawawa River flowing northeast, and the Madawaska River flowing east and southeast.

Chapman (1975) shows the regional physiography of this area as being dominated by shallow till cover amongst rocky uplands. This pattern is broken by a few major spillway features which trend to the southwest.

Bedrock Geology

The bedrock geology of the map area is poorly understood and much of the area has not been mapped in detail. The area is underlain predominantly by migmatitic metasediments and granite gneisses of the Central Gneiss Belt, Grenville Province. Although considered a rather monotonous sequence, this belt has been divided by Davidson and Morgan (1980) into a series of structural domains. The map area lies within the Algonquin Domain, described as heterogeneous in many aspects except for metamorphic grade which is uniformly in 2-pyroxene granulite facies.

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[1] Geologist, Engineering and Terrain Geology Section, Ontario Geological Survey, Toronto

There are 2 major trends of lineaments in the map area, 1 trending north-northwest and the other trending east-northeast. In addition there is a subsidiary north-trending lineament.

A description of specific bedrock features along Highway 60 within the Algonquin Park boundary is provided by Guillet (1969).

Quaternary Geology

The direction of the last (Late Wisconsinan) glacial advance over the map area was moderately consistent. Numerous glacial striae were measured over the entire area indicating an ice movement trending 205° ± 15°. Local deflections, caused primarily by bedrock topography, are minor, but extend the range in direction to 160° and 230°. In contrast to the relatively simple advance pattern, the deglacial history provides a variety of materials and depositional sequences.

Till cover, in general, is less extensive and thinner than that encountered to the north in the 1982 mapping. The till is predominantly a thin stony veneer over much of the map area. It is notable for its extent and thickness in the following areas: near the western end of the park along Highway 60; in the Fletcher Lake area of the Kawagama Lake sheet; and north of Little Kinnisis Lake on the Kawagama Lake sheet. Till varieties range from extremely compact, fissile, lodgement till southwest of Tea Lake, to melt-out tills and flow tills throughout the area. Some of the latter varieties have been found overlying extensive outwash sequences.

Ice-contact deposits are also much less common than to the north. There are a few small eskers and isolated kame terraces throughout the area. A major kame complex surrounds Trout Lake in the northern part of the Algonquin map area. This marks the southern extent of a much larger sequence to the north. Ice-proximal deltaic sands and gravels occur in the southwestern portion of the Kawagama Lake sheet and are associated with the easternmost boundaries of glacial Lake Algonquin in that area.

Outwash deposits are extensive over the map area, and consist primarily of well sorted sands and subsidiary gravels. These deposits occupy most lowland channels and bedrock valleys. One major outwash sequence transects the map area in a southwesterly direction. Its valley is now occupied by the Oxtongue River. Two other prominant systems, both in the Algonquin map area, are those presently occupied by the North Madawaska drainage system in the east, and by the Tim River in the north.

Glaciolacustrine deposits are confined to 2 main areas, but are also located in isolated pockets throughout the map area. The most extensive deposits are found in the southwestern corner of the Kawagama Lake map sheet. They consist primarily of varved silts and clays and are located very near the present Lake of Bays shoreline as well as within the Oxtongue River Valley. These deposits are associated with the easternmost extent of glacial Lake Algonquin, as reported by Chapman (1975). Similar deposits occur in pockets around the shores of Tom Thomson, Little Doe, and Fawn Lakes within Algonquin Park. These appear to be part of a separate and isolated proglacial lake. This is supported by the absence of Lake Algonquin-type glacial relict fauna in these lakes as reported by Martin and Chapman (1965). Sandy lacustrine deposits are extensive around the northern end of Canoe Lake and around the southern shore of Kawagama Lake.

Accumulations of organic matter, in the form of peat and muck, are widespread. The most extensive deposits are associated with outwash and alluvium along the major drainage channels. Isolated accumulations of peat, in excess of 1.5 m, are also found in the southwestern portion of the Kawagama Lake sheet.

Land Use Applications

The Quaternary history of the area mapped provides several features of economic, interpretive, and land use interest. A few features of specific interest to the Algonquin Park interpretive program include:

1. the Cannisbay Lake-Madawaska River area, with kame terraces, complex outwash sequences, and evidence for the occurrence of large remnant ice blocks
2. the array of ice-contact deposits around Trout Lake
3. the veneer of glaciolacustrine deposits in the Tom Thomson Lake area
4. the till deposits between Tea Lake and the West Gate, unique in the area for thickness and variety of structure

These features are closely associated with the high traffic corridors of the major canoe routes and camping areas.

Most of the areas of prime aggregate potential occur outside or near the park boundaries. Within the map area, the deposits of highest aggregate potential include the gravelly outwash in the Tasso to McCraney Lakes area, the deltaic outwash northeast of the Lake of Bays, and the mixture of beach and ice-contact gravels along the southwestern shore of Kawagama Lake.

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No. S23 Quaternary Geology of the Matheson and Lightning River Areas, District of Cochrane

U.J. Vagners[1]

THIS PROJECT IS PART OF OPERATION BLACK RIVER-MATHESON (BRiM) WHICH WAS FUNDED EQUALLY BY THE ONTARIO MINISTRY OF NORTHERN AFFAIRS AND ONTARIO MINISTRY OF NATURAL RESOURCES.

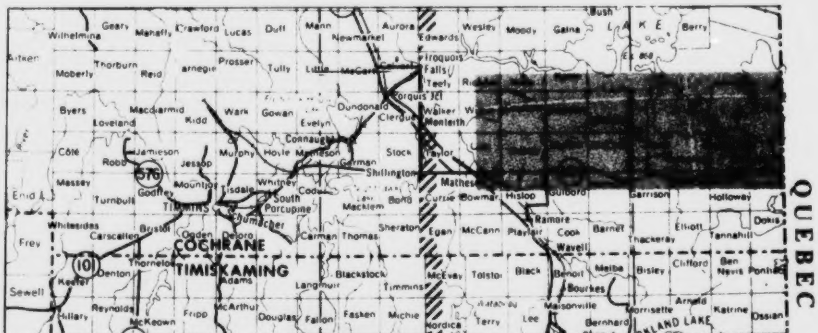
Introduction

The Matheson and Lightning River map areas (42 A/9 and 32 D/12 respectively) are bounded by Latitudes 48°30′ and 48°45′N, and Longitudes 79°30′ and 80°30′W. The Quaternary geology mapping completed during the 1983 field season involved the examination and assessment of materials as they occur in natural and man-made exposures along lakeshores, river and creek banks, road cuts, and excavations. These observations were supplemented by traverses along abandoned mineral exploration and lumbering roads, test pitting, and the use of soil probing equipment. Extensive use was made of 1:15 840 scale aerial photographs and to lesser degree 1:63 360 aerial photographs.

Bedrock Geology

The Matheson and Lightning River map areas are largely underlain by intermediate and mafic metavolcanics of Early Precambrian (Archean) age. Felsic metavolcanics have been noted within the area, the majority being located in the Matheson map area. Metasediments also occur in the area. Intruding these rock types are major intrusive rocks (of Early Precambrian age) which are distributed throughout the area. Metamorphosed mafic and ultramafic rocks are common. A large felsic intrusive complex is located in the northeastern part of the area. The youngest bedrock formations in the area are diabase dikes of Late Precambrian age.

The bedrock geology of the Matheson and Lightning River map areas has been compiled by Pyke *et al.* (1973).


Wilhelmina
Geary
Mahaffy
Crawford
Lucas
Duff
Mann
Newmarket
Aurora
Edwards
Wesley
Moody
Gaina
Bush
Berry
Aitken
Moberly
Thorburn
Reid
Carnegie
Prosser
Tully
Little
McCart
Iroquois Falls
Teefy
Byers
Loveland
Macdiarmid
Kidd
Wark
Gowan
Evelyn
Dundonald
Clergue
Iroquois Jct
Walker
Monteith
Connaught
Côté
Robb
Jamieson
Jessop
Murphy
Hoyle
Matheson
German
Stock
Taylor
Shillington
Massey
Godfrey
Mountjoy
Tisdale
Whitney
Cody
Matheson
Enid L.
Turnbull
Timmins
South Porcupine
Macklem
Bond
Currie
Bowman
Hislop
Guibord
Garrison
Holloway
Whitesides
Bristol
Schumacher
Carman
Thomas
Sheraton
Egan
McCann
Playfair
Ramore
Cook
Barnet
Thackeray
Elliott
Tannahill
Dokis
Frey
Carscallen
Ogden
Deloro
COCHRANE
Wavell
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TIMISKAMING
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Benoit
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Reynolds
Fripp
McArthur
Douglas
Fallon
Fasken
Michie
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Terry
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Arnold
Katrine
Ossian
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Doyle
Musgrove
Geikie
Cleaver
McNeil
Robertson
Sheba
Dunmore
Bompas
Grenfell
Teck
Gauthier
McVittie
McGarry
Childerhose
Bartlett
Lebel
66
Larder Lake
Crother
McBride
Nassaard
Beemer
English
Zavitz
Hincks
Argyle
Baden
Alma
Holmes
Burt
Eby
Otto
Dane
Boston
McElroy
Hearst
Fadden
48°
11
Northrup
Roblin
Gouin
Moher
Semple
Hutt
Montrose
Bannockburn
Powell
Cairo
Flavelle
Gross
Blain
Marquis
Pacaud
Catharine
Skead
Rattray
82°
81°
80°
624
Middleboro
Haran
Emerald
Nursey
Sothman
Halliday
Midlothian
Doon
Yarrow
Matachewan
Willison
Davidson
Sharpe
Savard
Chamberlain
Marter
Bayly
Mulligan
Kimberley
QUEBEC

LOCATION MAP Scale: 1:1 584 000 or 1 inch to 25 miles

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Physiography

The Matheson and Lightning River map areas are situated within the Great Clay Belt and are part of a physiographic division of the Canadian Shield known as the Abitibi Upland (Bostock 1970).

Elevations within this area range from 265 m above sea level (a.s.l.), the water level of the Abitibi River and Lake Abitibi, to a high point of 488 m a.s.l. on the Ghost Range, which is part of a mafic to ultramafic intrusive complex.

Quaternary Geology

Hughes (1960) mapped the surficial geology of the Matheson map area at a scale of 1:126 720; and Baker *et al.* (1980, 1982) mapped the Quaternary geology immediately south of the present map areas at a scale of 1:50 000.

The oldest Quaternary deposit noted in the Matheson and Lightning River map areas is a Wisconsinan silty sand till. Till exposures are quite scarce, with the best exposures found along lakeshores, river banks, and in man-made excavations. Striations and associated directional features indicate regional ice flow from north-northwest towards south-southeast at approximately azimuth 165°, however, local variations in the range azimuth 120° to 200° were noted. The ice flow towards the southwest corresponds to an earlier part of the glaciation, whereas the direction in the range azimuth 120° to 155° reflects the control of ice-flow direction by west-northwest-trending bedrock ridges.

Ice-contact stratified deposits consisting of eskers, kames, and deltas, occur throughout the study area. The most notable esker is the Munro Esker, with other eskers noted in Bowman, Hislop, Beatty, Garrison, Rand, Lamplugh, and Holloway Townships.

Kames are associated with the eskers and the best developed examples occur in Bowman, Michaud, Munro, McCool, Warden, Milligan, Garrison, Rand, and Marriott Townships.

Good examples of ice-contact deltas were noted in Lamplugh and Holloway Townships.

The ice-contact stratified deposits consist of sands and gravels which locally contain cobbles, boulders, and silt.

Following the retreat of the glacier, glacial Lakes Barlow and Ojibway inundated the area, leaving behind washed bedrock outcrops and developing, on the easily reworked ice-contact stratified drift material, beach and bar features. Shallow-water lacustrine sand and gravel deposits occur between 290 and 335 m a.s.l. The best examples of shoreline features are found in Munro, McCool, Warden, and Milligan Townships along the western and eastern sides of the Munro Esker. A lower erosional shoreline scarp was noted in several places around Lake Abitibi, at between 275 and 290 m a.s.l.

Fine-grained (deep-water) lacustrine sediments deposited in Lakes Barlow and Ojibway occur as silt and clay throughout the map areas below an elevation of 305 m a.s.l. These are the most common deposits in the map areas. They are massive in the upper portion, and become layered (varved) with depth.

Once the lake levels had dropped and exposed the land, eolian processes became active in the development of dunes on the fine- to medium-grained sand deposits of ice-contact and lacustrine origin. The best examples of dunes are found in Guibord, Michaud, Munro, McCool, Garrison, and Harker Townships. One ventifact was found near Lake Monahan in McCool Township.

Upon emergence of the land, accumulations of organic matter, in the form of peat, began to form in swamps and on stream flood plains.

Economic Geology

Sand and gravel are the most important commodities in the map areas. Several pits are operated in the Watabeag Esker near Matheson and along Highway 101 to the east. The pits along Highway 101 are in the following locations: a) McCool Township (Munro Esker); b) an esker near Collins Lake in Garrison Township; and c) deposits in Harker Township and Holloway Township. Many other pits are worked intermittently to satisfy local needs for mineral exploration and lumbering projects. The potential for developing additional sand and gravel deposits is high. Areas worth noting are:

1. Watabeag Esker Complex, Bowman Township
2. esker, Faulk Lake, Wilkie Township
3. esker, Lawlar Lake to Painkiller Lake
4. Munro Esker Complex, Guibord, Michaud, Munro, McCool, Warden, Milligan, and Kerrs Townships and the Chesney Bay area
5. esker, Collins Lake and Abitibi Indian Reserve
6. esker-kame-delta complex, Lamplugh Township
7. ice-contact stratified drift and lacustrine deposits around the Ghost Range
8. esker-kame deposits, Holloway Township
9. several more ice-contact and lacustrine deposits in Holloway, Marriott, Frecheville, and Stoughton Townships

At the moment the lacustrine clay is not utilized for any commercial purposes. Guillet (1977), in a regional study, commented that clays of the area are generally limy and of marginal interest, and Hughes (1956) reported that bricks made from lacustrine clay near Matheson weathered and disintegrated rapidly.

Peat bogs in the area are generally shallow (less than 2 m deep), although several have a large areal extent. Some of these may have potential for the development of fuel and/or horticultural peat-moss extraction at some time in the future.

During the last 20 years, studies of the overburden (till and ice-contact stratified drift deposits) have been utilized to help locate bedrock sources of precious metals which occur in overburden. Some attempts were and are being made to recover gold from placer deposits in the Munro Esker (Ferguson and Freeman 1977, p.8,9,10,22,65,164,165,166,167).

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No. 24 Geology of the Paleozoic Outliers on the Canadian Shield

D.J. Russell[1]

Introduction

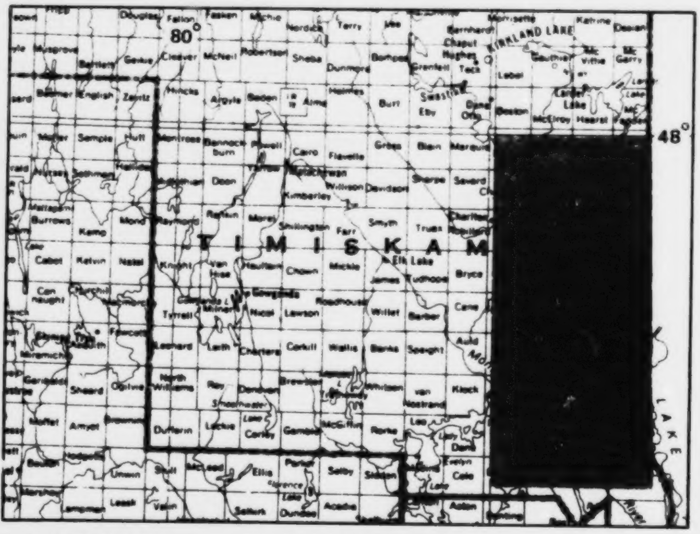
Short periods of field work were carried out in the Lake Timiskaming and Renfrew County areas to complete mapping initiated during the 1981 field season. Russell (1981) described the location and stratigraphy, as then known, of these outliers. In addition, core recovered from borehole LT-1, drilled in 1963 to determine the cause of a distinct magnetic anomaly near New Liskeard, and now stored at the Atlantic Geoscience Centre, Halifax, Nova Scotia, was relogged.

Lake Timiskaming Outlier

The Ordovician stratigraphy of this outlier was defined by Sinclair (1965) (Table 1). Both surface outcrops and the drill core from borehole LT-1 confirm the presence of the 4 units described. However, some changes in location of contacts between the formations in the drill core are warranted. The Silurian stratigraphy has never been rigorously defined, although Sanford (Poole *et al.* 1971) formalized some previously used names, applying them to the lower part of the section. Table 2 shows the newly defined, comprehensive Silurian stratigraphic nomenclature for the Lake Timiskaming area. A full explanation of the significance and reasons for the changes in Ordovician and Silurian stratigraphy is given in Russell (in preparation).

Renfrew County Outliers

Following the work of Williams and Rae (this volume), a new stratigraphic nomenclature has been applied to these Ottawa Valley fault blocks. Terminology used by Liberty (1969) in the Lake Simcoe area has been extended, with some modification, to the Ottawa-St. Lawrence Lowland. Thus, the Ottawa Formation of Russell (1981) becomes the Simcoe Group, further subdivided as



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

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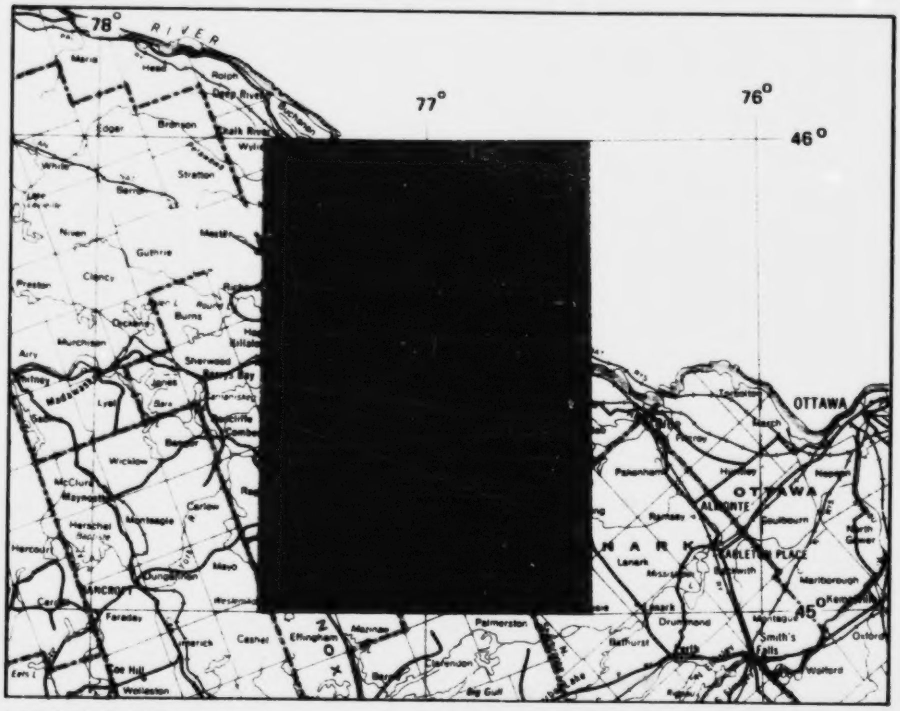
TABLE 1 ORDOVICIAN STRATIGRAPHY OF LAKE TIMISKAMING OUTLIER (after Sinclair 1965)

MIDDLE AND UPPER ORDOVICIAN		
	Dawson Point Formation	Liskeard Group
	Farr Formation	
	Bucke Formation	
	Grigues Formation	

TABLE 2 REDEFINED SILURIAN STRATIGRAPHY OF LAKE TIMISKAMING OUTLIER

MIDDLE SILURIAN	Upper Thornloe Formation	
	Lower Thornloe Formation	
	Evanturel Creek Formation	Wabi Group
	Cabot Head Formation	
LOWER SILURIAN	Manitoulin Formation	


78°
RIVER
77°
76°
46°
45°
OTTAWA
OTTAWA
ALMONTE
CARLETON PLACE
Smith's Falls

LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

TABLE 3 REDEFINED PALEOZOIC STRATIGRAPHY OF RENFREW COUNTY OUTLIERS

UPPER ORDOVICIAN		
	Billings Formation	
MIDDLE-UPPER ORDOVICIAN		
	Lindsay Formation	Simcoe Group
MIDDLE ORDOVICIAN		
	Verulam Formation	
	Bobcaygeon Formation	
	Gull River Formation	
	Rockcliffe Formation	
LOWER ORDOVICIAN		
	Oxford Formation	

shown in Table 3. Also, as shown in this table, the presence of the Rockcliffe Formation in this area has been confirmed.

Although a complete section through the Paleozoic rocks is not known from outcrop or drillcore in this area, the known thicknesses are such that several contacts between Paleozoic and Precambrian rocks, previously shown as unconformable (e.g. on the southern side of the Bromley outlier; Lumbers 1982) are in fact faulted contacts.

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No. S25 Paleozoic Geology of the Ottawa-St. Lawrence Lowland, Southern Ontario

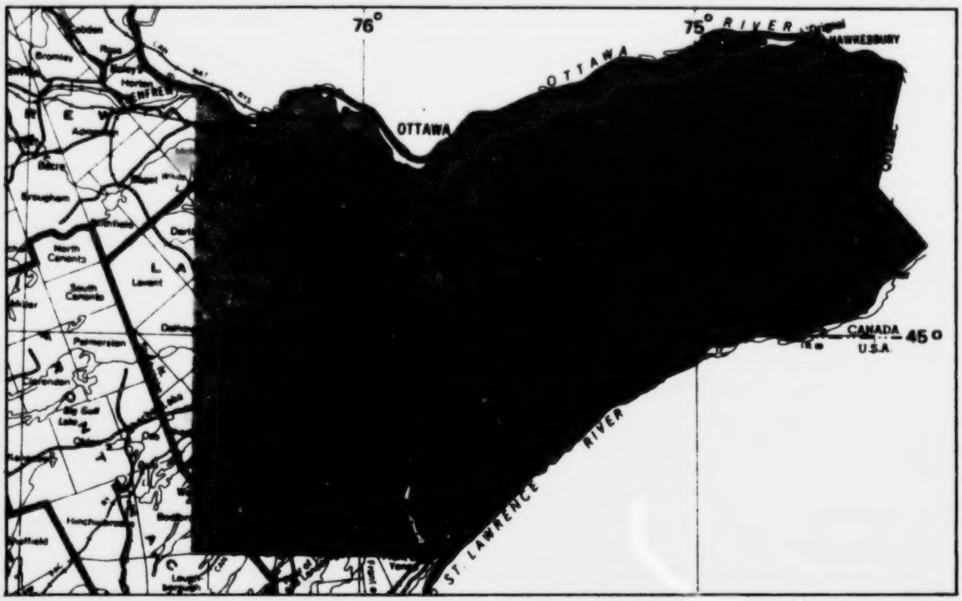
D.A. Williams[1] and Andrea Rae[2]

THIS PROJECT IS PART OF THE SOUTHEASTERN ONTARIO GEOLOGICAL SURVEY (SOGS) WHICH WAS FUNDED EQUALLY BY THE FEDERAL DEPARTMENT OF REGIONAL ECONOMIC EXPANSION (DREE) AND THE ONTARIO MINISTRY OF NATURAL RESOURCES UNDER THE MINERALS PROGRAM OF THE EASTERN ONTARIO SUBSIDIARY AGREEMENT.

Introduction

Geological mapping of the Ottawa-St. Lawrence Lowland during the summer of 1983 was a continuation of the 1981 and 1982 mapping programs (Carson 1982; Williams and Wolf 1982), and involved completion of mapping in the Quyon (31 F/9) and Arnprior (31 F/8) map areas, and additional examination of the following map areas: Carleton Place (31 F/1), Perth (31 C/16), Westport (31 C/9), Ottawa (31 G/5), Kemptville (31 G/4), Merrickville (31 B/13), Brockville (31 B/12), Mallorytown (31 B/5), Thurso (31 G/11), Russell (31 G/6), Winchester (31 G/3), Morrisburg (31 B/14), Hawkesbury (31 G/10), Alexandria (31 G/7), Cornwall (31 G/2), Lachute (31 G/9), Vaudreuil (31 G/8), and Huntingdon (31 G/1). The report area is bounded by the Ottawa and St. Lawrence Rivers, Longitude 76°30′W, and the Ontario-Quebec border.

Mapping was also conducted in the Peterborough-Kingston (Carson 1980, 1981a, 1981b) and Pembroke-Renfrew (Russell 1981) areas, in order to establish a uniform stratigraphic nomenclature which is applicable to the Ottawa-St. Lawrence Lowland.



LOCATION MAP **Scale: 1:1 584 000 or 1 inch to 25 miles**

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TABLE 1 **PALEOZOIC STRATIGRAPHY OF THE OTTAWA-ST. LAWRENCE LOWLAND, SOUTHERN ONTARIO**

Upper Ordovician	Queenston Formation
	Carlsbad Formation
	Billings Formation
Middle-Upper Ordovician	Lindsay Formation
Middle Ordovician	Verulam Formation
	Bobcaygeon Formation
	Gull River Formation
	Rockcliffe Formation
Lower Ordovician	Oxford Formation
	March Formation
Cambro-Ordovician	Nepean Formation
	Covey Hill Formation
	Basal Unit
	UNCONFORMITY
Precambrian	Undifferentiated metamorphic and igneous rocks

General Geology

The Paleozoic stratigraphy of the Ottawa-St. Lawrence Lowland is summarized in Table 1. Paleozoic bedrock outcrop is generally abundant in the western part of the region and within approximately 10 km of the Ottawa River, and consists of cliff and quarry sections and extensive areas of bedrock pavement. In the eastern part of the region, and more than approximately 10 km from the Ottawa River, a thick surficial sequence commonly overlies the bedrock and outcrop is generally sparse to moderate; scattered exposures occur in river valleys, and there are some areas of pavement (within which quarries have generally been developed). A thickness of up to 1130 m of Paleozoic rock exists in the Ottawa-St. Lawrence Lowland.

Precambrian rocks outcrop to the west and south of the Lowland in the Arnprior, Carleton Place, Perth, Westport, Brockville, and Mallorytown map areas, and Precambrian inliers are common in the western and southern parts of the Lowland. Precambrian rocks outcrop to the north of the Lowland in the Gatineau region of Quebec; a continuation of the Precambrian outcrop area to the south of the provincial boundary extends through the Arnprior area and the western part of the Ottawa area, and other continuations exist in the Thurso and Hawkesbury areas.

Poorly sorted reddish brown to green conglomerate and conglomeratic sandstone unconformably overlie the Precambrian basement at several localities in the western part of the Lowland. The clasts are up to boulder size, and consist of Precambrian quartzite, marble, granite, and gneiss. This basal unit was previously assigned to the Covey Hill Formation (discussed below) by Williams and Wolf (1982).

The Covey Hill Formation consists of non-calcareous feldspathic fine- to coarse-grained quartz sandstone and quartz-pebble conglomerate; the thickness decreases from several hundred metres in the eastern part of the Lowland (where it has been intersected in several drillholes) to zero in the western part.

The Nepean Formation consists of calcareous to non-calcareous fine- to coarse-grained quartz sandstone. A basal pebble or cobble conglomerate approximately 1 m thick commonly occurs. The fresh surface is white to buff, and the weathered surface is white to reddish brown. Crossbedding is common, and cylindrical structures or "pillars" occur in the western part of the Lowland.

The March Formation consists of interbedded quartz sandstone, sandy dolostone, and dolostone. The lower contact is the base of the lowermost dolomitic bed, and the upper contact is the top of the uppermost sandy bed. The sandstone beds are identical in lithology to those of the Nepean Formation, and the dolostone beds to those of the Oxford Formation (discussed below). A lower member of the March Formation, consisting of blue-grey sandy dolostone with thin interbeds of sandstone and dolostone, occurs in the northern part of the Mallorytown map area and the southern part of the Brockville map area.

The Oxford Formation consists of light to dark grey, sublithographic to fine crystalline dolostone. The weathered surface is light grey to buff to reddish brown. Stromatolites and calcite-filled vugs are common. In the eastern part of the Merrickville map area, the Oxford Formation contains chert nodules and quartz-filled vugs.

The Rockcliffe Formation consists of interbedded, fine-grained, light greenish grey quartz sandstone and green shale. A basal conglomerate occurs locally. The upper part of the formation is characterized by interbeds of silty dolostone, sublithographic to fine crystalline limestone with shaly partings, and calcarenite (the St. Martin Member); the calcarenite occurs only in the eastern part of the Lowland.

The Gull River Formation consists of interbedded silty dolostone, lithographic to fine crystalline limestone, shale, and fine-grained calcareous quartz sandstone. The silty dolostone is pale greenish grey to medium grey, sublithographic to fine crystalline, and thin to thick bedded; it weathers buff to reddish brown, and conchoidal fractures and calcite-filled vugs are common. The lithographic to fine crystalline limestone is tan to dark grey, medium- to thick-bedded, and weathers white to bluish grey; intraclasts, oolites, and white calcite "eyes" (resulting in "birdseye" texture) are common. Lower and upper members (Units A and B, and Unit C, respectively, of Williams and Wolf 1982) are mappable, and it is recommended that the formation be similarly subdivided into 2 members elsewhere in southern Ontario. The basal bed of the lower member is a black ostracod-bearing shale approximately 1 m thick which has been described by Raymond (1911, p.190), and the upper contact is the top of the uppermost dolomitic bed. The upper member consists of lithographic to fine crystalline limestone and its upper contact is the top of the uppermost lithographic bed. The upper beds of the upper member contain abundant *Tetradium*.

The Bobcaygeon Formation (Unit D of Williams and Wolf 1982) consists of interbedded calcarenite and sublithographic to fine crystalline limestone. The calcarenite is light to medium grey, thin bedded to massive, and weathers bluish to brownish grey; crossbedding, intraclasts, and stylolites are common. The sublithographic to fine crystalline limestone is grey to brownish grey, thin bedded to massive, and weathers bluish to brownish grey. Chert occurs as nodules up to 20 cm in diameter, and beds and lenses up to 5 cm thick. Lower and upper members are mappable, and it is recommended that the formation be similarly subdivided into 2 members elsewhere in southern Ontario. The contact between the 2 members is the base of the lowermost calcarenite bed.

The Verulam Formation (Unit E of Williams and Wolf 1982) consists of interbedded biocalcarenite, calcarenite, sublithographic to fine crystalline limestone, and calcareous shale. The biocalcarenite, calcarenite, and sublithographic to fine crystalline limestone are grey to brownish grey, very thin to medium bedded, and weather bluish grey to brown. Shale interbeds are up to 10 cm thick.

The Lindsay Formation consists of interbedded sublithographic to fine crystalline limestone (commonly nodular), calcareous shale, and calcarenite. The sublithographic to fine crystalline limestone and calcarenite are grey to brownish grey to brown. The calcareous shale is dark brown to black to dark grey. Two members are mappable; shale occurs as interbeds up to 5 cm thick in the lower member (Unit F of Williams and Wolf 1982), and is more abundant in the upper member.

The Billings Formation consists of dark brown to black noncalcareous shale with 2 cm interbeds of calcareous siltstone. Pyritized cephalopods, trilobites, and inarticulate brachiopods occur. The lower part of the Billings Formation and the underlying Eastview Formation of Wilson (1946) consist of calcareous shale and, following the proposals of Russell and Telford (in press), are assigned to the upper member of the Lindsay Formation.

The Carlsbad Formation consists of interbedded dark grey shale, fossiliferous calcareous siltstone, and silty bioclastic limestone. Crossbedding is common, and beds are up to 30 cm thick. The siltstone and limestone have a medium grey fresh surface and a buff to reddish brown weathered surface.

The Queenston Formation consists of red to light greenish grey, laminated to thick bedded, slightly calcareous siltstone and shale. Interbeds of silty bioclastic limestone occur in the lower part of the formation. The red colour is predominant, with the light greenish grey colour occurring along joints, along bedding planes, and as reduction spots.

Three carbonatite dikes, striking generally east, and up to 40 cm thick, are exposed in the Francon Quarry at Blackburn. The dikes are probably of Cretaceous age (Bolton and Liberty 1972, p.21-22). Another carbonatite dike is exposed along the southern bank of the Ottawa River, between the Carillon Dam and the Ontario-Quebec border; the dike strikes east-northeast and is up to 1 m thick.

Structural Geology

Steeply dipping normal faults and fault zones with up to 900 m of vertical displacement, and striking in a range from southeast to northeast, are of common occurrence in the region and constitute the Ottawa-St. Lawrence Lowland fault system. The southern boundary of the fault system extends generally east-northeastward from the Rideau Lakes, crossing the Ontario-New York border 5 km northeast of Morrisburg. The Queenston Formation, the uppermost Paleozoic rock unit of the Lowland, occurs in fault blocks in the southwestern part of the Russell map area.

Bedding, normally close to horizontal, often dips steeply adjacent to faults and within fault zones. Fault traces are generally straight but are commonly curved in the vicinity of fault junctions, which generally consist of a single fault branching from another fault. Many major fault junctions, involving a larger number of faults, occur. The displacement at a fault junction is approximately equal to the sum of the displacements along each set of faults which branches from the junction.

Stress-relief buckles occurring near Ottawa, in the Fallowfield quarry of H.J. McFarland Construction Company, and at the top of the eastern end of the Fallowfield quarry of Warren Paving and Materials Group Limited, have been described by Adams (1982) and Russell, Graham, and White (1982). Quarry floor buckles also occur in the Cornwall quarries of Cornwall Gravel Company and Permanent Concrete Limited, and a stress-relief buckle located 90 m northeast of the South Mountain quarry of Cruickshank Construction Limited was observed.

Economic Geology

The Nepean Formation is a source of silica sand for use in the glass and foundry industries (Powell and Klugman 1979). Wynne-Edwards (1967, p.125-126) described the occurrence of small hematite concentrations, common at the base of the Nepean Formation. Many small quarries in the Nepean Formation, now abandoned, were sources of stone used in buildings (including many federal government buildings in Ottawa) and in the construction of the Rideau Canal (Hewitt 1964).

Copper-uranium mineralization (chalcopyrite-thucolite) occurs in the March Formation in the vicinity of South March (Charbonneau, Jonasson, and Ford 1975).

A gypsum bed approximately 1.5 m thick occurs in the Oxford Formation in the vicinity of Cornwall (Guillet 1964, p.71).

The March, Oxford, Rockcliffe (St. Martin Member), Gull River, and Bobcaygeon Formations are currently being quarried at many localities for use as aggregate. Many of the quarries were described by Hewitt and Vos (1972). The March Formation is a source of skid-resistant aggregate (Rogers 1980). Dolomitic limestone beds in the lower member of the Gull River Formation and cherty beds in the Bobcaygeon Formation are alkali reactive, and are unacceptable for use as concrete aggregate unless a low-alkali cement is used (Rogers 1983).

The oil shale potential of the upper member of the Lindsay Formation has been investigated by Johnson (1982).

The Queenston Formation is quarried near Russell for use in brick making by Domtar Construction Materials Limited (Guillet 1967, p.76-78).

Post-Ordovician calcite-fluorite-barite-celestite-galena-sphalerite-chalcopyrite veins occur in the region. The veins strike east to southeast, and are up to 7 m thick. Faults (particularly fault junctions) are an important control for vein localization.

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No. 26 Aggregate Resources Inventory Program

Staff of the Aggregate Assessment Office[1]

Introduction

Field work was conducted in southern Ontario and northern Ontario during the 1983 field season as part of the Aggregate Resources Inventory Program. Field investigation is an integral step in the preparation of each aggregate resources inventory report. The results of field activities undertaken in 1983 will be published in Aggregate Resources Inventory Papers or released in Open File Reports as applicable. The main areas involved in field investigations were:

1. Grey County
2. Sault Ste. Marie area, Algoma District
3. Espanola area, Sudbury District

Field investigations consisted of the following activities: examination of potential aggregate deposits, existing pits and quarries, natural and man-made exposures, as well as auger drilling. All active and abandoned pits were investigated and at each site the following observations were made: face height, percentage of gravel and sand, and the presence of deleterious material such as chert, shale, clay, silt, and oversized boulders. Other information gathered during the pit investigations included the intended uses of the granular material and the presence of stock piles, water-filled ponds, crushing plant, and rehabilitation work.

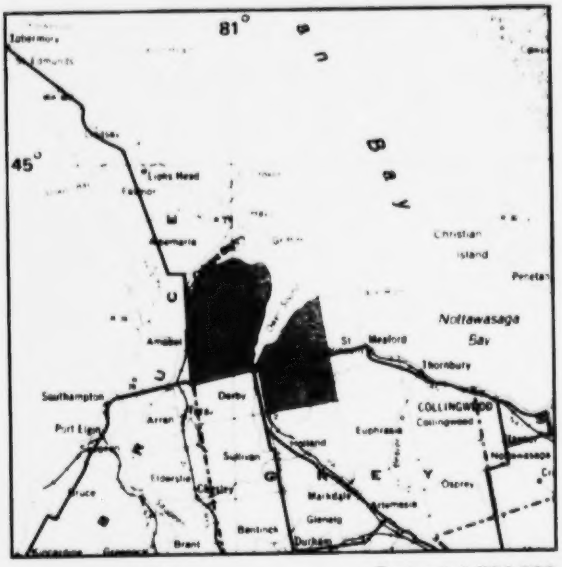
Abandoned pits also were evaluated to provide additional information on resource areas. Estimates of the amount of material previously extracted from these pits were made to enable resource tonnage calculations. Active and abandoned quarries were also visited. At these sites, the height of the face was noted, as well as bedrock geology, and the presence of deleterious materials. The purpose of the field investigations was to confirm and add to information gathered from various sources such as existing geological reports and maps, data from files of the Ontario Ministry of Transportation and Communications, and water well data from the Ontario Ministry of the Environment.

In areas where little pre-existing data were available or where the presence of buried granular material was suspected, drilling and geophysics work was undertaken. The combined use of a small portable drill rig and geophysical equipment (conductivity and hammer seismic) provided more information, permitting a better means of assessment of potentially significant sand and gravel deposits.

Grey County

Field investigations continued in Grey County during the 1983 field season resulting in the completion of field work for Keppel, Sarawak, and Sydenham Townships. Detailed field assessment indicates that these 3 townships have considerably smaller reserves of surficial aggregate when compared to the townships in south Grey County, which possess abundant, regionally significant deposits of sand and gravel.

Surficial deposits containing locally significant amounts of sand and gravel are found in a small number of scattered ice-contact stratified drift deposits and in numerous glaciolacustrine beach and some glaciolacustrine plain deposits. The ice-contact stratified drift deposits include



LOCATION MAP

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[1] Aggregate Assessment Office, Engineering and Terrain Geology Section, Ontario Geological Survey, Toronto

kame-like features and a few small eskers which were deposited in association with the retreating Georgian Bay ice sheet (Sharpe and Jamieson 1982; Feenstra in preparation). These deposits are generally thin and consist of gravelly sand often contaminated by lenses of clay and silt and fragments of Queenston Formation shale. The coarser glaciolacustrine sediments were derived from the local till by wave action of the waters of glacial Lakes Algonquin and Nipissing which accompanied the decaying ice sheet. The beach deposits are numerous and generally contain a high percentage of subrounded to rounded, tabular, medium- to coarse-grained gravel in the matrix of often silty to clayey fine- to medium-grained sand. Small areal extent, shallow depth, excessive contamination by silt and clay, and considerable variability limit the potential of these deposits to supply only limited quantities of low specification aggregate for local use.

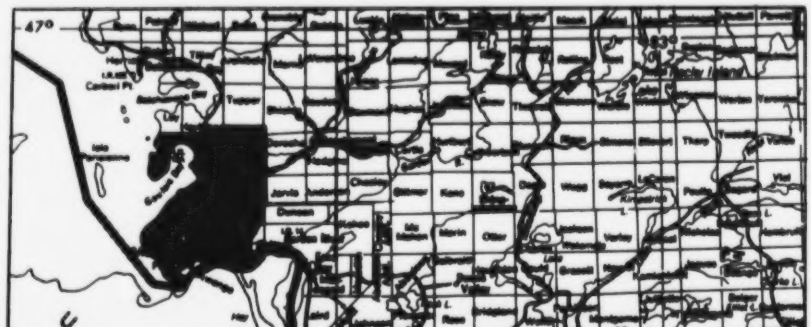
Drift cover is generally much greater than 8 m in all of the townships with the exception of the southeastern part of Sydenham Township where drift is in excess of 15 m. A large number of extensive bedrock exposures consisting of dolostone of the Amabel and Guelph Formations are located in all 3 townships forming the top of the Niagara Escarpment. At the time of field checking, there was 1 licenced quarry in Sydenham Township where Amabel Formation dolostone is mined to produce a full range of high quality aggregate products. In Keppel Township, the same bedrock formation is mined in 2 licenced quarries to produce ledgerock, flagstone, and ornamental stone. The Eramosa Member of the Amabel Formation is mined at these quarries. The bituminous or shaly partings present in the rock allow easy extraction of the thin bedrock layers. However, the Eramosa Member is not suitable for aggregate production in this area because of the thin layers and shaly partings. Thinly drift-covered areas of the Guelph Formation also hold future mining potential. This rock formation, however, is best suited for the production of high purity dolomitic lime.

In light of the dwindling surficial sand and gravel resources the large bedrock resources, suitable for aggregate production should be considered for resource protection in the "Official Plans" of the Ontario Ministry of Natural Resources.

Sault Ste. Marie Area

The Sault Ste. Marie project area includes the City of Sault Ste. Marie, the Corporation of the Township of Prince, and the geographic townships of Dennis, Pennefather, Aweres, Kars, Fenwick, and Van Koughnet. The area is underlain by rocks of Precambrian and Cambrian age (Frarey 1977). Generally, the topography is very rugged, displaying large areas of outcrops. A thin veneer of drift covers some of the lower lying area. Areas of thick overburden are found only in the city and in Prince Township south of the Gros Cap Batholith, and in the Goulais River valley in Fenwick and Van Koughnet Townships.

The predominant aggregate-bearing glacial sediments in the project area are glaciolacustrine beach and glaciofluvial outwash or deltaic top-set deposits (Cowan in preparation). The largest and most important sand and gravel deposit complex lies within the City of Sault Ste. Marie and it flanks onto the Gros Cap Batholith. The origin of these deposits is attributed to glacial Lake Algonquin. As the Laurentide ice sheet retreated from the project area some 11 000 years ago, large volumes of meltwater flowed in small rivers to lower elevations from the bedrock uplands (Gros Cap Batholith) carrying loads of sand and



LOCATION MAP **Scale: 1:1 584 000 or 1 inch to 25 miles**

gravel. These rivers deposited this material in a series of deltas along the Gros Cap Batholith which also served as the northern shore of glacial Lakes Algonquin and Nipissing near the end of the glacial period. The coarser material was subsequently resorted and spread along the shoreline in what can be seen as raised beach terraces, while finer grained sediments were carried farther out into the lake to form lacustrine plain deposits. The large beach deposit complex has been extensively mined for aggregates. At the time of field checking, there were 22 licenced gravel pits in this deposit alone. Pit faces expose 15 to 37 m of sand and fine- to coarse-grained gravel of extremely high quality (Deike 1983).

Outwash deposits containing similarly high quality gravel were deposited in terraces along the Upper Root River system and along the early Goulais River channel. The gravel along the Upper Root River system (which is the area along Highways 17 and 556 south of and near Heyden) is generally coarse grained and cobbly. The material was deposited directly on the irregular bedrock surface by fast-flowing glacial meltwaters issuing from the retreating ice front. High groundwater levels and recent residential development may limit the future availability of the good quality aggregate from these deposit areas.

The outwash deposit which occurs in east-central Van Koughnet Township is generally finer grained containing clean, sandy, fine- to medium-grained gravel. During the time of deposition as the Goulais River reached the flat-lying areas of west Van Koughnet and Fenwick Townships, meltwater velocity decreased resulting in the development of large deltaic sand deposits in these areas.

Good quality aggregate is also found in the St. Marys River. At the time of field checking, sand and gravel was draglined and barged to the shore by 1 local operator from an area licenced under the Beach Protection Act, southwest of Chene Island.

Additional shallow lacustrine beach deposits of lesser quality, generally forming a thin veneer on bedrock, are found on bedrock slopes around the Goulais River flatland and along the Goulais Bay/Lake Superior shoreline.

There is no history of quarrying for aggregate in the project area. Detailed sampling and analysis would be required to delineate high quality crushed stone quarry sites. Presently, there is 1 small quarry within the City of Sault Ste. Marie from which limited quantities of Jacobsville Formation sandstone are mined to produce decorative stone. This sandstone is weak and porous and therefore not suitable for use as construction aggregate (Russell 1982).

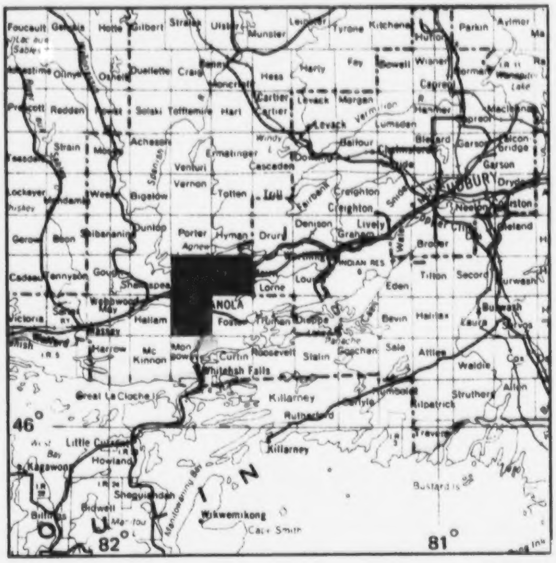
In view of the large sand and gravel resources existing in the Sault Ste. Marie area, it is not necessary at the present time to quarry bedrock for road construction aggregate.

Espanola Area

The Espanola project area consists of the Town of Espanola, the incorporated townships of Nairn and Baldwin, and the unorganized township of Merritt. The area is located southwest of Sudbury along King's Highways 17 and 6.

The bedrock in the report area has a rock-knob topography. During the last glacial advance, the ice deposited a thin veneer of till on some areas of the bedrock. During the withdrawal of the glacier, ice-contact material was deposited in the northwest and southwest sections of the report area. Two large ridges of this material are found in Baldwin Township, while in Merritt Township the material is deposited on the flanks of rock outcrops. Also during this time, meltwaters from the receding ice front laid down quantities of outwash material in the valleys between the rock outcrops, notably along the Spanish River. Following the disappearance of the ice, the area was covered by waters of glacial lakes which occupied the Lake Huron basin. The wave action of the water reworked the pre-existing glacial deposits, and fine sands were laid down in some areas, particularly on top of the outwash in the valleys.

The outwash deposits consist primarily of well sorted medium- to coarse-grained sand interlayered with beds of well sorted fine-grained gravel. In most places, the outwash is overlain by 1 to 1.5 m of fine lacustrine sands, which are not as well suited for aggregate use as the outwash. There are 2 areas of outwash which have potential for extraction. These deposits contain relatively higher


Foucault
Hotte
Gilbert
Munster
Tyrone
Kitchener
Hutton
Parkin
Aymer
Lac aux Sables
Ouellette
Craig
Hess
Harty
Fay
Bowell
Wisner
Capreol
Lake
Prescott
Redden
Solski
Tofflemire
Hart
Cartier
Levack
Morgan
Vermilion
Lumsden
Hanmer
Maclennan
Strain
Acheson
Windy L
Ermatinger
Cascaden
Dowling
Balfour
Blezard
Garson
Falconbridge
Garson
Spanish
Venturi
Vernon
Lockeyer
Bigelow
Totten
Trill
Fairbank
Creighton
Creighton
SUDBURY
Dryden
Neelon
Dunlop
Porter
Agnew
Hyman
Drury
Denison
Lively
Graham
Broder
Tennyson
Shakespeare
INDIAN RES
Tilton
Secord
Burwash
ANOLA
Lorne
Eden
Victoria
Hallam
Foster
Dieppe
Bevin
Halifax
Burwash
Kaura
Massey
Harrow
Mc Kinnon
Curtin
Roosevelt
Stalin
Panache
Goschen
Sale
Attlee
Waldie
Cox
Whitefish Falls
Great La Cloche I.
Killarney
Struthers
Allen
Rutherford
Kilpatrick
46°
Little Current
Howland
Killarney
Kagawong
Sheguiandah
Bustard Is
Billings
Bidwell
Manitowaning Bay
Wikwemikong
Cape Smith
82°
81°
N

LOCATION MAP

Scale: 1:1 584 000
or 1 inch to 25 miles

amounts of gravel than the other areas of outwash. The first area is located west of Nairn Centre. Numerous pits have been developed in this deposit. The second area is located halfway between Nairn Centre and Espanola. This deposit consists of terraced gravelly sands occupying the valley of the Spanish River.

The ice-contact ridges located in Baldwin Township consist of irregularly bedded and poorly sorted silty sand to coarse gravel. These deposits have the highest potential for producing significant amounts of crushable gravel in the report area.

The remaining deposits in the area are either small in extent or predominantly sandy. These deposits are suitable for local use as low-specification aggregate.

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No. S27 Peatland Inventory Project

J.L. Riley[1]

THIS PROJECT IS PART OF THE HYDROCARBON ENERGY RESOURCES PROGRAM (HERP), AND WAS FUNDED BY THE ONTARIO MINISTRY OF TREASURY AND ECONOMICS UNDER THE BOARD OF INDUSTRIAL LEADERSHIP AND DEVELOPMENT (BILD) PROGRAM.

Introduction

The principal objective of the Peatland Inventory Project is the evaluation of the resource potential of Ontario's numerous peat deposits, and to clarify preliminary estimates of this resource (163 $m^3 \times 10^9$ for Ontario south of the permafrost; Monenco Ontario Limited 1981). In working towards this objective in 1982-1983, four areas were chosen in which to complete detailed and reconnaissance studies of some major peatlands, and to document the distribution of peatlands in the study areas as a whole.

Within the 4 study areas, Hearst (16 600 km^2), Armstrong (3500 km^2), Pembroke (5800 km^2), and Peterborough (10 000 km^2), a total of 45 sites (ca. 11 000 ha) were studied in detail. Detailed study included elevation contour mapping, depth contour mapping, volume calculations, peatland classification mapping, peat type profiles, peat humification profiles, summary text, and site recommendations. A total of 84 other sites were studied at a less detailed level. The entire study areas were mapped for peatland types at 1:15 840 scale.

Other project objectives served by these procedures included the mapping of types of vegetation occurring on peatlands and the investigation of remote sensing techniques for the identification and characterization of peatlands. The latter objective involved work with satellite image interpretation and related field checks in the Armstrong area and an area northeast of Timmins, undertaken for the project by the Ontario Centre for Remote Sensing (OCRS), Toronto.

Reports on these studies have been published as Open File Reports of the Ontario Geological Survey and have provided sufficient information to make individual site evaluations of peat resources and to modify the inventory procedures for future field studies.

Location of Field Studies

The 4 study areas (Figure 1) were selected as representing areas of considerable peat resources and areas within which there was expressed interest in the evaluation being conducted.

The Hearst area (Longitudes 83°W to 85°W, and Latitudes 49°N to 50°N) contains extensive peatlands defined by and reflecting the surficial clay/silt deposits of proglacial Lake Barlow-Ojibway. Shallow peatlands probably cover about 10% of the area, with deeper peats concentrated only in more restricted basins.

The Armstrong area (Longitudes 88°30′W to 89°30′W, and Latitudes 50°N to 50°30′N) includes an eastern Lake Nipigon basin area of lacustrine and fluviolacustrine surficial deposits, and a western area of dominantly bedrock or very shallow tills over bedrock. The former area is characterized by peatlands in large, more or less symmetrical, shallow basins, while the latter area has much smaller, scattered peatlands which directly reflect the morphology of the Precambrian bedrock basins.

The Pembroke area (Figure 1) straddles the contact between Precambrian and Paleozoic bedrocks, with surficial outwash and glaciolacustrine deposits dominating the overburden. The largest peatlands occur in the basin of the proglacial Champlain Sea, in areas underlain by Paleozoic bedrock.

The Peterborough study area (Longitudes 77°30′W to 79°W, and Latitudes 45°15′N to 45°N) is also bisected by the Precambrian/Paleozoic contact. It is also characterized by larger, regular, and more shallow peat deposits south of the contact, and smaller and more dissected peatlands of less predictable depths in Precambrian basins in the northern half of the study area.

The Ontario Centre for Remote Sensing was involved in an evaluation of peat deposits in a 1700 km^2 area, 50 km northwest of Timmins (Longitudes 81°45′W to 82°20′W, and Latitudes 48°40′N to 49°N). The objectives of this study were to provide volume estimates and peat type characterization through a reconnaissance field study based on LANDSAT image interpretation of the area. The Ontario Centre for Remote Sensing also ran a brief field reconnaissance of the Armstrong area (Figure 1) in order

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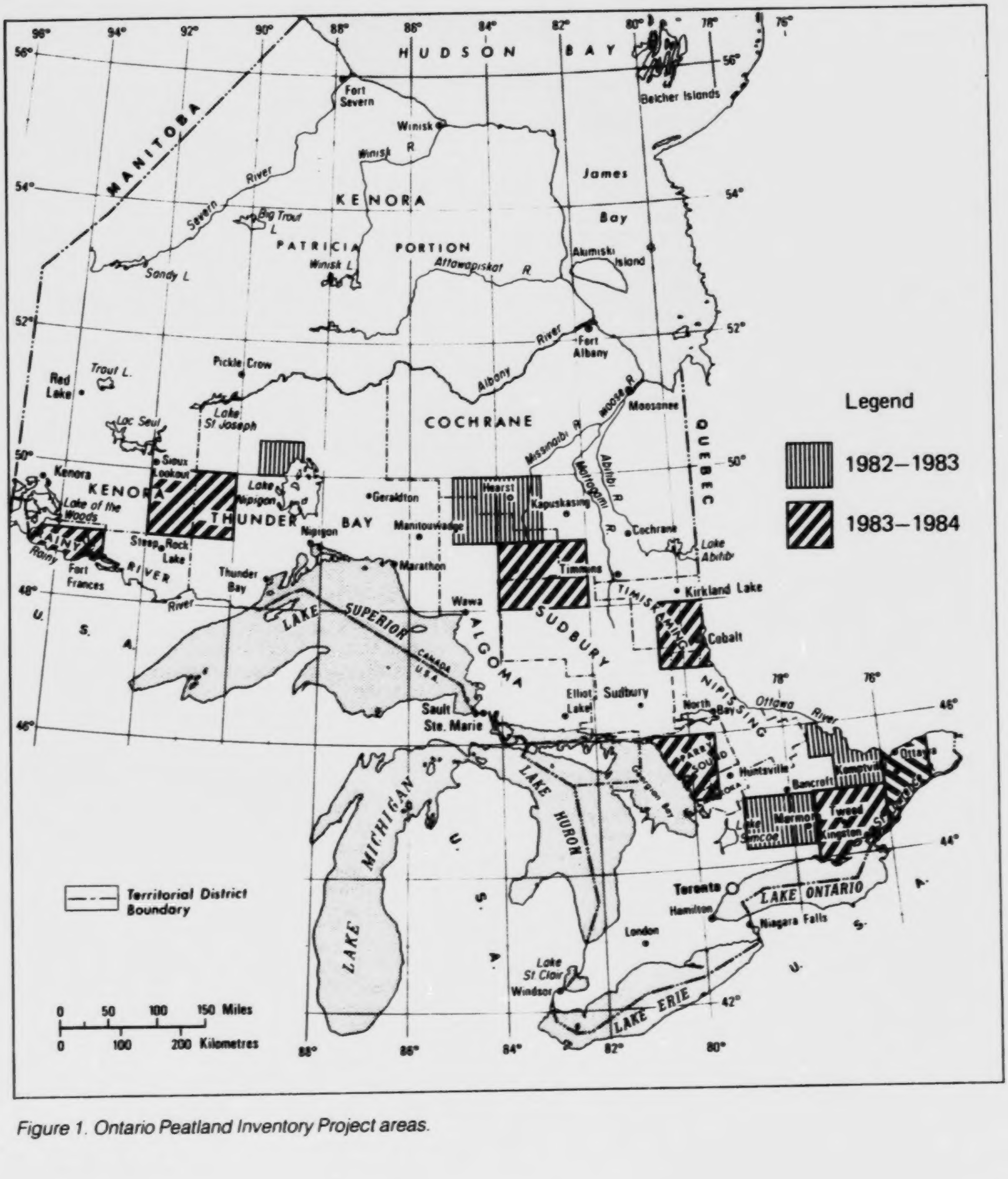
HUDSON BAY
James Bay
Belcher Islands
Fort Severn
Winisk
Winisk R
Severn River
Big Trout L
Sandy L
KENORA
PATRICIA PORTION
Attawapiskat R
Akimiski Island
Fort Albany
Albany River
Pickle Crow
Trout L.
Red Lake
Lac Seul
Lake St Joseph
MANITOBA
COCHRANE
Missinaibi R
Moose R
Moosonee
QUEBEC
Abitibi R
Mattagami R
Hearst
Kapuskasing
Cochrane
Lake Abitibi
Timmins
Kirkland Lake
Cobalt
TIMISKAMING
Kenora
Lake of the Woods
Sioux Lookout
Lake Nipigon
Geraldton
Manitouwadge
THUNDER BAY
Nipigon
Marathon
RAINY RIVER
Steep Rock Lake
Fort Frances
Thunder Bay
LAKE SUPERIOR
CANADA
U.S.A.
Wawa
ALGOMA
SUDBURY
Elliot Lake
Sudbury
North Bay
NIPISSING
Ottawa River
Sault Ste. Marie
PARRY SOUND
Huntsville
Bancroft
Kemptville
Ottawa
Tweed
Kingston
Marmora
Lake Simcoe
LAKE MICHIGAN
LAKE HURON
Georgian Bay
Toronto
Hamilton
LAKE ONTARIO
Niagara Falls
London
Lake St Clair
Windsor
LAKE ERIE
U. S. A.
Legend
1982–1983
1983–1984
Territorial District Boundary
0 50 100 150 Miles
0 100 200 Kilometres
96° 94° 92° 90° 88° 86° 84° 82° 80° 78° 76°
56° 54° 52° 50° 48° 46° 44° 42°

Figure 1. Ontario Peatland Inventory Project areas.

to provide a basis for comparison of traditional survey techniques and reconnaissance methods based on satellite imagery.

Procedures

Field studies were undertaken by 4 consulting companies, 1 in each study area. Their procedures were directed by standard project specifications and field visits by Ontario Geological Survey staff. All data were recorded on standard record forms. The procedures for 1982-1983 were based on the Peatland Inventory Project conducted by the province of New Brunswick from 1975 to 1981 (Keys and Ferguson 1982).

In general, the procedures involved the outlining, indexing, and mapping of all peatlands, using aerial photography. Prospective sites for detailed study were selected on the basis of size, peatland type, proximity to population centres, and accessibility. On each detailed site, a grid was laid out made up of baselines and intersecting sidelines at 500 m intervals. Sample points at each 100 m along these transects were usually levelled (14 sites by transit, 17 by photogrammetric methods). At each sample point, a core was characterized stratigraphically by change in peat type and peat humification, as well as fine fibre content and wetness.

Each sample point was also characterized in terms of substrate, percentage tree cover, stump content (Keskitalo 1982), modified Radforth cover type (Keys and Ferguson 1982), microtopography, and peatland classification (modified from Jeglum *et al.* 1974).

These data were the basis for isopach (depth) mapping, elevation mapping, peatland classification mapping, transect profiles of peat type and peat humification, calculation of volumes of surficial (Von Post H1-3) and humified (H4+) peat, and summary text on drainage, site clearing, and resource potential.

At each detailed study site, a representative core was collected for laboratory analysis of physical and chemical measures. Laboratory procedures were based on standard methods which will be published in a forthcoming Open File Report.

Laboratory analysis included the following tests: moisture content (% wet, % dry), bulk density (g/cc wet, g/cc dry), rubbed fibre (% dry), conductivity (µmhos/cm), pH-H_2O, pH-$CaCl_2$, cation exchange capacity (meg/100 g), absorptive capacity, ash (% dry), volatile matter (% dry), calorific value (cal/g), carbon (% dry, organic, total), nitrogen (% dry), hydrogen (% dry), sulphur (% dry), oxygen (by difference), As, Hg, Ca, Fe, Pb, Al, P, K, Mg, Mn, Cu, and Zn (all parts per million). Control on precision and determination of practical detection limits was attempted through blind replicates and blind duplicates of a known Holland Marsh peat.

Survey Results and Peat Sample Analysis

Results of the 1982-1983 Peatland Inventory Project are being published as Open File Reports of the Ontario Geological Survey: Hearst (Dendron Resource Surveys Limited 1983), Pembroke (Ecological Services for Planning Limited 1983), Peterborough (Bird and Hale Limited 1983), and Timmins (Pala and Boissonneau in press).

A summary of peatland areas studied and estimates of peat volumes (Table 1) shows a total peatland area of over 11 000 ha studied in detail, with average sizes of areas ranging from 160 to 266 ha (overall 250 ha average). The similarity of sizes of detailed study sites may reflect the site selection process by consultants rather than any regional patterns of peatland distribution.

The complete study areas were site typed at 1:15 840 scale in terms of peatland type, with tabulations of results showing predictable differences in peatland types between study areas. Treed bog and fen, conifer swamp and, to a lesser degree, open bog and fen dominate the 2 northern sites, while hardwood swamps and marshes are

TABLE 1 SUMMARY OF RESULTS FOR THE 1982-1983 PEATLAND INVENTORY PROJECT

AREA	TOTAL AREA SITE TYPED (km^2)	NUMBER OF DETAILED SITES	PEATLAND AREA (ha)	VOLUME SURFICIAL PEAT (10^6m^3)	TOTAL HUMIFIED PEAT (10^6m^3)	TOTAL VOLUME OF PEAT (10^6m^3)	NUMBER OF RECONNAISSANCE SITES
Hearst	16 630	15	3 976	17.15	60.7	77.85	33
Armstrong	3 470	6	962	21.8	5.4	27.2	8
		(6)	(3 404)	(70.1)	(14.6)	(84.7)	
Pembroke	5 770	7	1 836	7.25	35.7	42.75	10
Peterborough	10 000	17	4 529	4.77	26.15	30.92	33
Total	35 870	45	11 303 ha (13 745 ha)	50.97 (99.27)	127.95 (137.15)	178.92 (236.42)	83

Note: Bracketted values represent results from separate remote sensing/reconnaissance study of Armstrong area.

more frequent cover types in the peatland of southern Ontario.

Satellite image interpretations of peatlands northwest of Timmins were ground-checked at a reconnaissance level in 1982 and 1983. Although mapping (1:50 000) of physiognomic types at the most detailed level was not found to be possible, mapping of the following units at a less detailed level was found to be reliable: open bog (0 to 10% tree cover), low density treed bog (10 to 15% tree cover), medium density tree cover (15 to 25% tree cover), high density treed bog (>25% tree cover), treed poor fen, conifer swamp, treed graminoid fen, treed shrub-rich fen, and hardwood and thicket (including some swamp). Volume estimates were made by averaging peat depth/humification values for reconnaissance points in particular mapping units, and multiplying those average values by the areal extent of the mapping units. At only 1 site (Moberly Township Bog), was there sufficient data from standard isopach mapping to allow comparison of standard detailed volume calculations with this remote sensing/reconnaissance method. At this site, the estimates by both methods were within 10% of each other.

In terms of volume estimates and laboratory analysis of collected peat samples, the 45 detailed sites contain more than 127 000 000 m^3 of humified peat (H4+, = 44 400 000 tonnes) with an average calorific value of 4380 cal/g (n=170) and an average moisture content of 79.6% (n=171). The volume of surficial peat (H1-3) estimated for the 45 sites was a minimum of 51 000 000 m^3 (17 830 000 tonnes). It should be noted that the average calorific value for these surficial peats was also 4380 cal/g (n=58).

Ash content of the humified peat (H4+) varied considerably from site to site; averaging 10% in the Hearst area (n=62), 14.6% in the Peterborough area (n=69), 11% in the Pembroke area (n=32), and 6.9% in the Armstrong area (n=8). It is not possible at this stage to determine whether these reflect any general regional patterns, but higher ash content in southern peatlands may reflect the prevalence of swamps in the south, many of which are seasonally flooded.

Sulphur content ranged as high as 2.3% dry weight in the Peterborough area but, overall, averaged 0.44% (n=229). Figures 2 and 3 illustrate the variability of important peat parameters with peat humification levels and dominant peat types. Of these parameters, regionally different results can be seen only in ash content and peat pH (acidity) at this stage of the inventory. All data and procedures are to be presented in a future Open File Report.

Future Field Studies

On the basis of the 1982-1983 program, certain modifications are considered desirable for future operations.

1. More elaborate project specifications were needed in order to raise the quality of survey work and to standardize both field studies and reports. All reports were judged to be lacking in data analysis and overview. There was an obvious need for standardized summary table formats in order to provide data for regional perspective, comparisons of sites, and correlation of peat depth/types with peatland types.
2. Peatland site typing of entire study areas from air photos may be beyond the abilities of most of the consulting community at the present time and, as a result, may provide questionable data of considerable cost to the project. The time and expertise would be better spent on detailed site surveys.
3. As a result of this conclusion and from the perceived need to more specifically direct survey work to specific large and accessible peatlands, the staff of the Ontario Geological Survey will, in future, select all detailed and reconnaissance sites within study areas. Rather than attempting to preview the entire air photo coverage of study areas, sites will be selected from 1:50 000 LANDSAT feature imagery for which some preliminary thematic interpretation had been attempted by the Ontario Centre for Remote Sensing. In this way, consultants would be presented with a more detailed outline of the work required in each study area, and Ontario Geological Survey would have more control of site selection. Modification of work plans during actual field work is certainly expected, but only in consultation with Ontario Geological Survey staff.
4. The regional mapping of peatland types and extrapolation of detailed volume data to smaller sites would be accomplished more reasonably by applying regional peat depth/type characteristics from detailed studies to the calculations of peatland areas by satellite image interpretations.
5. The accuracy of detailed peatland classification mapping and site descriptions would be enhanced by the addition of biological or botanical staff to each group of survey crews.
6. The need for a standard method of volume calculations would be addressed in the 1983-1984 project specifications.
7. More experimentation was necessary in terms of cost-effective means of levelling site transects to produce accurate elevation mapping. Several combinations of transit work, photogrammetric techniques, electronic topochains, and airborne laser levelling will be attempted.
8. The necessity to recognize the more important role of woody peats in Ontario than in either the Maritime Provinces or Scandinavia is acknowledged. Rather than recognizing sedge (C), sphagnum (S), and bryales (B) peats as the 3 major peat dominants, sedge (C), moss (including sphagnum, S), and wood (L) peats should be viewed as the most important peat constituents in Ontario.
9. There must be more than single physical peat cores retrieved from detailed study sites for laboratory analy-

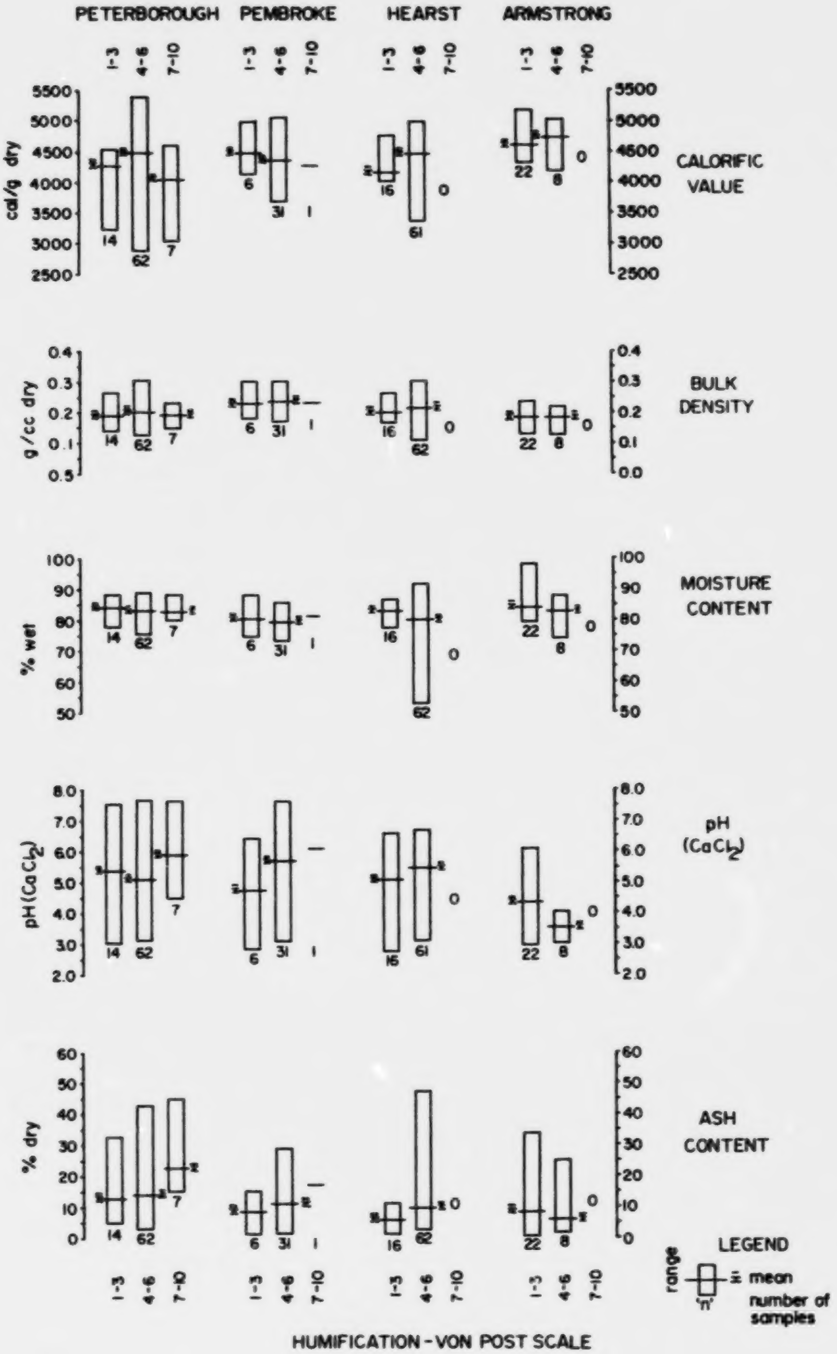

Figure 2. Degree of peat humification versus selected laboratory tests for peat samples from 1982-1983 study areas.

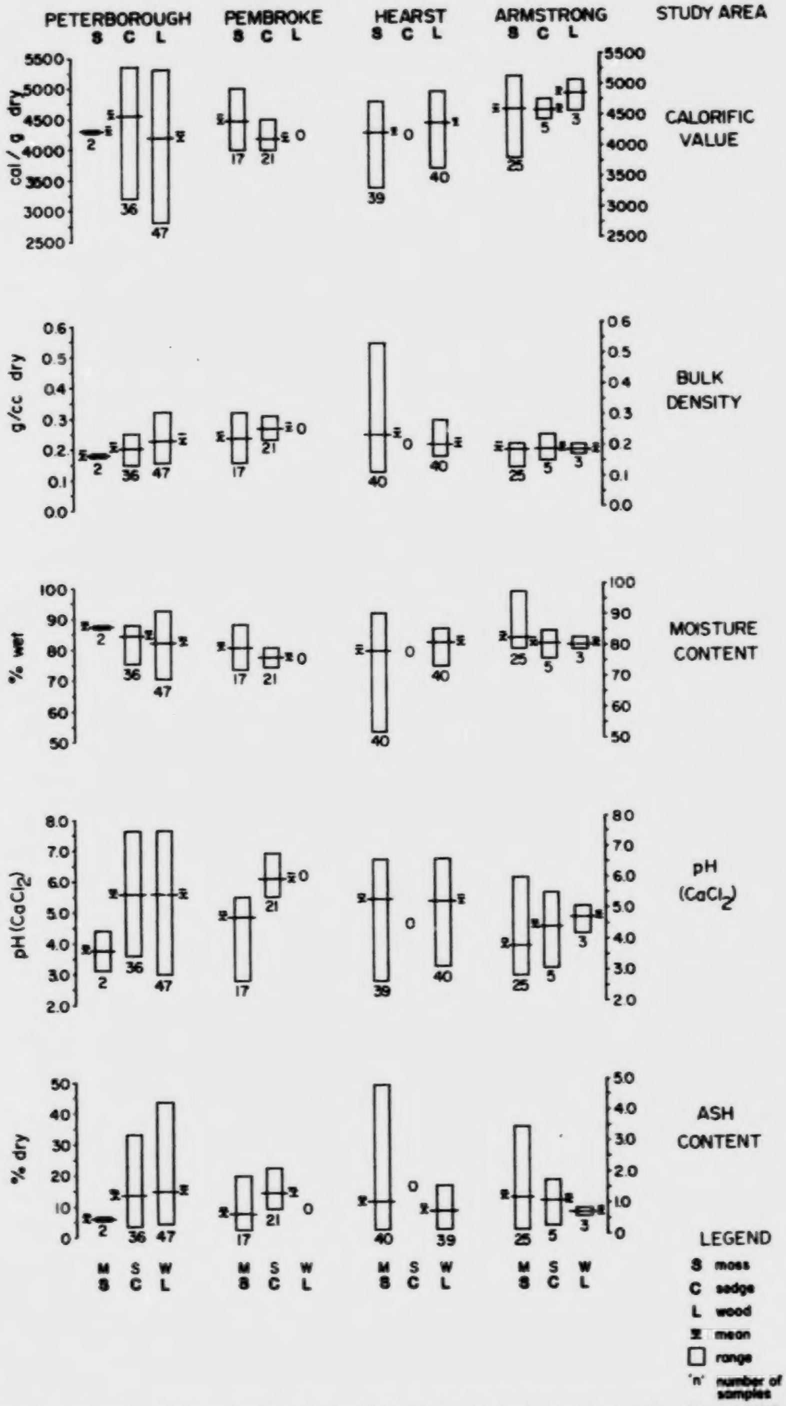

Figure 3. Major peat type versus selected laboratory tests for peat samples from 1982-1983 study areas.

sis, in order to reflect differences within peatlands and to minimize the possibility of anomalous results based on single samples.

10. In order to standardize laboratory procedures for private laboratories doing sample analysis, better documentation was needed for the procedures themselves and for the precision limits possible by those procedures. Detailed analytical methods and the development of multiple peat material standards (of known quality) are needed.
11. The necessity to pursue comparative studies of volume calculations by remote sensing/reconnaissance methods and standard inventory methods is recognized, in order to increase the confidence with which detailed site data can be extrapolated to satellite imagery of sites not studied in detail.

These considerations are being addressed in the 1983-1984 Peatland Inventory Project. The 7 study areas selected for 1983-1984 are indicated on Figure 1, and the scope of these studies is summarized on Table 2. Open File Reports on the 7 areas will be available in early 1984.

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TABLE 2 **SUMMARY OF PLANNED 1983-1984 PEATLAND INVENTORY PROJECT**

	NUMBER OF DETAILED SITES	PEATLAND AREA (ha)	NUMBER OF RECONNAISSANCE SITES	PEATLAND AREA (ha)
Rainy River	10	17 170	19	10 407
Ignace	10	14 000	17	9 160
New Liskeard	7	7 500	11	5 700
Ottawa-Brockville	10	12 700	15	7 500
Parry Sound	8	2 700	10	2 600
Folleyet	6	4 700	9	1 900
Belleville-Kingston	10	6 500	23	8 800
Total 1983-1984	61	65 270	104	46 067

No. S28 Oil Shale Assessment Project

M.D. Johnson[1]

THIS PROJECT IS PART OF THE HYDROCARBON ENERGY RESOURCES PROGRAM (HERP), AND WAS FUNDED BY THE ONTARIO MINISTRY OF TREASURY AND ECONOMICS UNDER THE BOARD OF INDUSTRIAL LEADERSHIP AND DEVELOPMENT (BILD) PROGRAM.

Introduction

The Oil Shale Assessment Project is aimed at a preliminary evaluation of the potential of Ontario Paleozoic black shales as a source of petroleum. Initial examination suggested that 3 of the Paleozoic shale units had a sufficiently high hydrocarbon content to warrant study: the Upper Ordovician Collingwood shale beds (recently redefined as a member of the Lindsay Formation (Telford and Russell in press), the Devonian Marcellus Formation, and the Devonian Kettle Point Formation. In 1983, attention was focused on the Devonian units with some continuing work on the Collingwood shales. Johnson (1982) has a description of previous work carried out on the Collingwood shales.

Location

Black shales of Devonian age subcrop/outcrop in 2 areas of southwestern Ontario. The Marcellus Formation forms a lenticular body, mainly beneath Lake Erie, with its northern edge subcropping on land in the Port Stanley area (Figure 1). The Kettle Point Formation subcrops/outcrops along a north-trending belt between Lakes Erie and Huron in the Chatham-Sarnia area (Figure 1). In much of their subcrop areas these formations are covered by thick deposits of Pleistocene glacial and lacustrine materials.

General Geology

The Marcellus Formation has a maximum thickness of about 25 m. These grey to black shales overlie brown limestones of the Dundee Formation, and are in turn overlain by grey shales and shaly limestones of the Hamilton Group. Due to the similarity between the Hamilton and Marcellus shales, the precise geographic and stratigraphic limits of the Marcellus are poorly known.

The Kettle Point Formation has a maximum thickness in Ontario of about 70 m. However, it thickens rapidly to the south beneath Lake Erie and to the north beneath Lake Huron to several hundred metres. In Ontario, the upper surface of the unit has been eroded to a gently undulating plain.

The Kettle Point Formation is a siliceous shale, often containing large calcite concretions. The shales are black or dark grey with intervals of grey-green laminae. The unit is easily distinguished from overlying clastic units of the Port Lambton Group and the underlying limestone of the Ipperwash Formation (Hamilton Group).

Shallow Drilling Program

During the Fall of 1982 and Winter of 1983, 25 shallow boreholes were drilled through the Devonian oil shales; 20 were drilled through the Kettle Point and 5 through the Marcelus (Table 1). These holes were all less than 125 m deep and were all of NQ size (4.7 cm diameter). Most holes were geophysically logged prior to plugging. Core recovery was good with about 925 m collected. Lithological descriptions and geophysical logs for each core are being released in open file reports.

During August 1983, an additional shallow borehole was drilled through the Upper Ordovician Collingwood shales at Clarksburg, near Georgian Bay. This hole was drilled at P diameter (8.5 cm diameter) to provide bulk samples for testing purposes.

Deep Drilling Program

To examine the quality and thickness of the oil shale units at depth, a series of 9 deep boreholes have been drilled through the Paleozoic sequence in southern Ontario (Table 2). All but one (Hole Number 82-2) of the deep holes terminated in Precambrian crystalline rocks, thus providing complete sections through the Paleozoic sequence as well as new information about the Precambrian basement.

These boreholes have yielded some 5100 m of core. This core will be used to establish subsurface reference sec-

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[1] Geologist, Engineering and Terrain Geology Section, Ontario Geological Survey, Toronto.

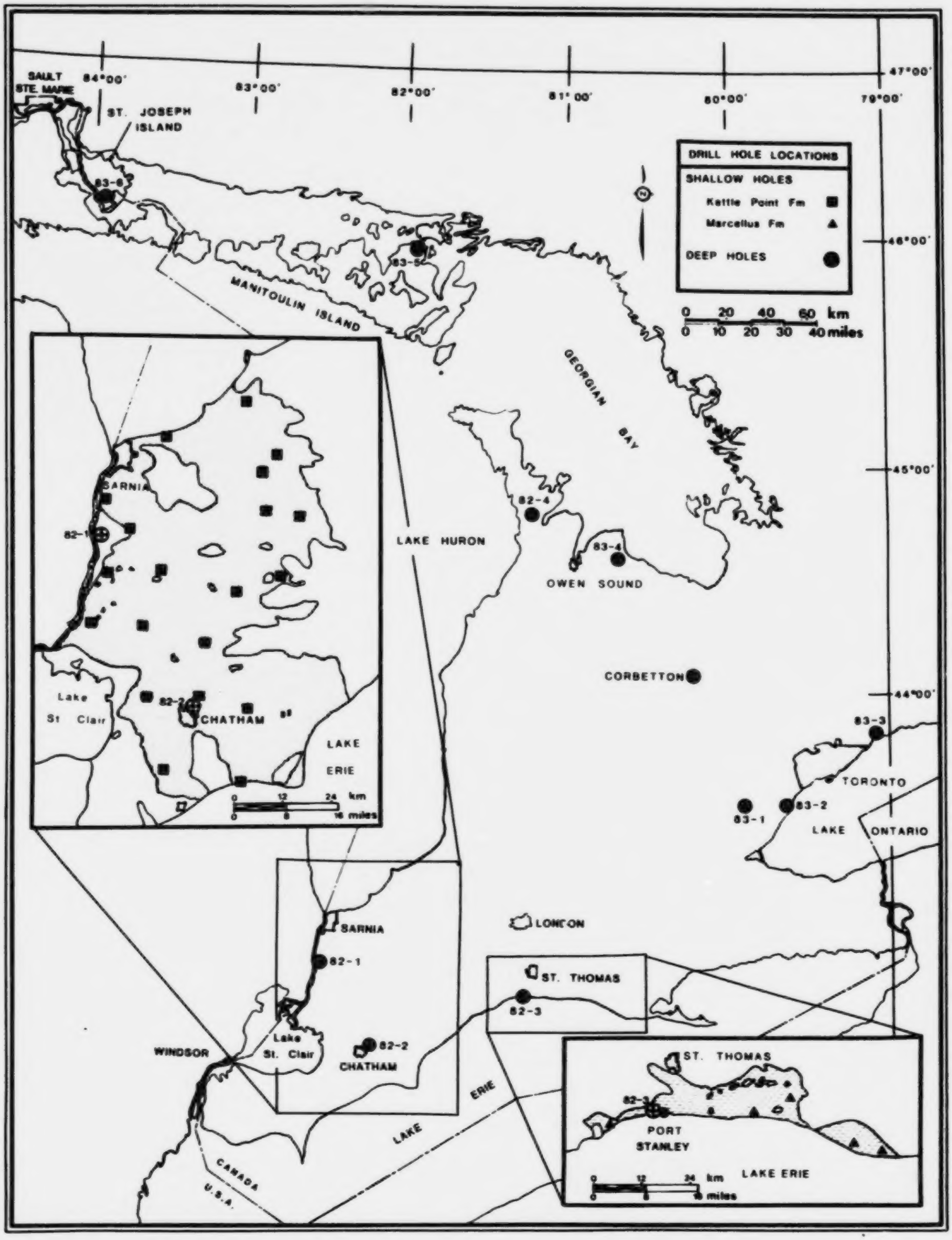
84°00'
83°00'
82°00'
81°00'
80°00'
79°00'
47°00'
46°00'
45°00'
44°00'
SAULT STE. MARIE
ST. JOSEPH ISLAND
83-6
83-5
MANITOULIN ISLAND
GEORGIAN BAY
DRILL HOLE LOCATIONS
SHALLOW HOLES
Kettle Point Fm ■
Marcellus Fm ▲
DEEP HOLES ●
0 20 40 60 km
0 10 20 30 40 miles
82-4
LAKE HURON
83-4
OWEN SOUND
CORBETTON
83-3
TORONTO
83-1
83-2
LAKE ONTARIO
SARNIA
82-1
Lake St Clair
82-2
CHATHAM
LAKE ERIE
0 12 24 km
0 8 16 miles
LONDON
ST. THOMAS
82-3
WINDSOR
Lake St. Clair
ERIE
LAKE
CANADA
U.S.A.
PORT STANLEY
LAKE ERIE

Figure 1. Summary of deep holes and 1983 shallow holes.

TABLE 1 **DEVONIAN SHALLOW DRILLING RESULTS**

HOLE NUMBER	LOCATION				UNITS ENCOUNTERED	TOTAL DEPTH OF DRILLING (m)
	COUNTY	TOWNSHIP	LOT	CONCESSION		
Kettle Point						
10	Kent	Raleigh	24	I	Kettle Point/Hamilton	58.07
11	Kent	Raleigh	6,7	A	Kettle Point/Hamilton	64.33
12	Kent	Dover	19	VII	Kettle Point/Hamilton	46.02
13	Kent	Chatham	10	I	Kettle Point/Hamilton	52.12
14	Kent	Harwich	19	XI,XII	Kettle Point/Hamilton	67.13
15	Kent	Camden	1	V,VI	Kettle Point/Hamilton	73.41
16	Kent	Chatham	21	II	Kettle Point/Hamilton	97.84
17	Kent	Chatham	4	II	Kettle Point/Hamilton	103.93
18	Lambton	Sombra	10,11	XIII	Kettle Point/Hamilton	116.15
19	Lambton	Sombra	15.26	VII	Kettle Point/Hamilton	91.74
20	Kent	Dawn	20,21	VIII	Kettle Point/Hamilton	30.78
21	Lambton	Euphemia	22	IV,V	Hamilton	22.95
22	Lambton	Brooke	21,22	VII	Kettle Point/Hamilton	30.99
23	Lambton	Brooke	4	VII,IX	Kettle Point/Hamilton	47.55
24	Lambton	Moore	21	V	Kettle Point/Hamilton	125.54
25	Lambton	Moore	409	R.P.#413	Kettle Point/Hamilton	102.29
26	Lambton	Sarnia	9,10	F.L.H.	Kettle Point/Hamilton	64.21
27	Lambton	Plympton	30	II,III	Kettle Point/Hamilton	40.03
28	Lambton	Warwich	13	II S.E.R.	Kettle Point/Hamilton	38.30
29	Lambton	Plympton	24,25	XV	Kettle Point/Hamilton	46.97
Marcellus						
5	Norfolk	Houghton	1	IX	Marcellus/Dundee	117.90
6	Norfolk	Houghton	1,7	IV	Marcellus/Dundee	101.19
7	Elgin	Bayham	6	III	Dundee	63.09
8	Elgin	Malahide	26	I	Marcellus/Dundee	99.82
9	Elgin	Dunwich	24	XII	Dundee	59.13
83-4 Clarksburg	Grey	Collingwood	27	X	Lindsay (including Collingwood Member)	95.40

TABLE 2 **DEEP DRILLING RESULTS**

HOLE NUMBER	LOCATION				DEEPEST STRATA	TOTAL DEPTH OF DRILLING (m)
	COUNTY	TOWNSHIP	LOT	CONCESSION		
82-1	Lambton	Moore	18	Front	Precambrian	1380.75
82-2	Kent	Harwich	25	I E.B.R.	Cambrian	1180.80
82-3	Elgin	Yarmouth	Tract 3 Lot 9	I	Precambrian	502.90
82-4	Bruce	Albermarle	25	I W.B.R.	Precambrian	446.53
83-1	Halton	Nassagaweya	9	VII	Precambrian	637.64
83-2	Peel	Toronto	33	III	Precambrian	495.30
83-3	Durham	Pickering	18	—	Precambrian	251.50
83-5	Manitoulin	Howland	6	V	Precambrian	137.10
83-6	Algoma	Jocelyn	67	A	Precambrian	349.94

tions that will be valuable for the oil shale project, for defining regional stratigraphic frameworks, and to assist oil and gas exploration by the private sector.

Hydrocarbon Analyses

Selected portions of core from each borehole are being subjected to organic geochemical analysis by J.F. Barker and associates at the University of Waterloo under contract to the Ontario Geological Survey.

Analyses performed include total organic carbon, total inorganic carbon, kerogen hydrogen-carbon ratios, yield on pyrolysis, and the industry standard, the Fisher Assay. Results of this analytical work are to be released shortly in a series of open file reports.

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No. S29 Lignite Assessment Project, Moose River Basin, James Bay Lowland

P.G. Telford[1] and D.W. Sawicki[2]

THIS PROJECT IS PART OF THE HYDROCARBON ENERGY RESOURCES PROGRAM (HERP), AND WAS FUNDED BY THE ONTARIO MINISTRY OF TREASURY AND ECONOMICS UNDER THE BOARD OF INDUSTRIAL LEADERSHIP AND DEVELOPMENT (BILD) PROGRAM.

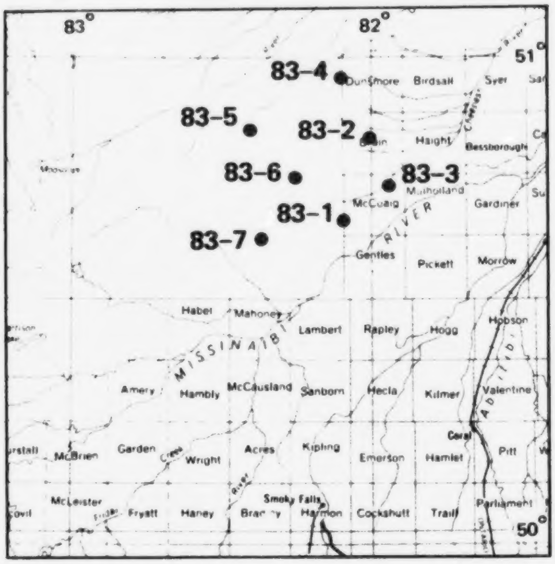
Introduction

During February-March 1983, a lignite reconnaissance drilling program was carried out in the Moose River Basin, James Bay Lowland. The work formed part of the Lignite Assessment Project, a component of the Hydrocarbon Energy Resources Program. The principal objective of the Lignite Assessment Project is to define the lignite resource potential of the James Bay Lowland and to stimulate private sector interest in the mineral resources of the region.

The 1983 drilling program was managed for the Survey by Watts, Griffis and McOuat Limited who subcontracted the drilling to Heath and Sherwood Drilling of Kirkland Lake. Helicopter support for the operation was provided by Huisson Aviation Limited of Timmins. After completion of the drilling, a borehole geophysical survey was carried out by Century Geophysical Corporation of Calgary. Watts, Griffis and McOuat prepared a report describing all aspects of the drilling operation and including lithological and geophysical logs of all the drillholes. This is to be released shortly as an Open File Report.

Location

A total of 7 holes, 10 to 26 km apart, were drilled in an area north of the Missinaibi River towards the eastern margin of the Moose River Basin (Location Map). The area of drilling is centred about 120 km southwest of Moosonee and about 60 km northwest of the well known lignite deposits at Onakawana. The closest all-weather road terminates at Smoky Falls at the southern margin of the James Bay Lowland, about 80 km to the south. Winter roads have been extended into the area from Smoky Falls and Hearst during previous private and public sector programs but these were not used during the 1983 program, which relied totally on helicopter support.


83°
82°
51°
50°
83-4
83-5
83-2
83-6
83-3
83-1
83-7
Dunsmore
Birdsall
Syer
Haight
Bessborough
Mulholland
McCuaig
Gardiner
RIVER
Gentles
Pickett
Morrow
Habel
Mahoney
Lambert
Rapley
Hogg
Hobson
MISSINAIBI
Amery
Hambly
McCausland
Sanborn
Hecla
Kilmer
Valentine
Coral
McBrien
Garden
Creek
Wright
Acres
Kipling
Emerson
Hamlet
Pitt
McLeister
Fryatt
Haney
River
Smoky Falls
Harmon
Cockshutt
Traill
Parliament

LOCATION MAP

Scale: 1:1 584 000
or 1 inch to 25 miles

General Geology

The Moose River Basin contains an approximately 600 m thick sequence of Paleozoic strata overlying Precambrian basement rocks. The southern margin of the basin is marked by a prominent east-trending fault-controlled escarpment that has truncated the Paleozoic sequence against basement rocks.

In the southeastern part of the basin the Paleozoic strata are overlain by up to several hundred metres thickness of unconsolidated Mesozoic sediments. The geographic limits of these Mesozoic sediments are imprecisely known but they range in age from Middle Jurassic to Lower Cretaceous (Telford and Verma 1982). The lignite deposits at Onakawana, as well as other lignite occurrences in the region (Telford and Verma 1978) lie within the Lower Cretaceous portion of the sequence.

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[2] Geotechnical Officer, Engineering and Terrain Geology Section, Ontario Geological Survey, Toronto.

The entire region is overlain by a sometimes very thick cover (up to 200 m) of Pleistocene glacial and glaciolacustrine deposits and Recent marine clays (Skinner 1973).

Drilling Results

Table 1 summarizes the drilling results. The 7 holes were successfully completed, involving 863.7 m of drilling. The deepest hole (83-06) was 179.9 m deep, while the shallowest (83-04) reached 101.1 m; the former contained 173.6 m of Pleistocene and Recent sediments overlying only 6.3 m of the Cretaceous Mattagami Formation. Approximately 770 m of borehole geophysical logging was carried out.

Four of the drillholes (83-01, 83-02, 83-04, 83-07) ended in rocks of definite Devonian age and a fifth hole (83-03) ended in a unit of possible Devonian age. The Devonian units consist of claystones of the Upper Devonian Long Rapids Formation or limestones of the Middle-Upper Devonian Williams Island Formation.

New lignite discoveries within the Mattagami Formation were made in drillholes 83-01 and 83-02, and numerous smaller seams were indicated in hole 83-07. The main seams in each of holes 83-01 and 83-02 were 5 to 6 m thick, occurring at depths of about 73 to 75 m. The seams in hole 83-07 were 0.5 to 1.9 m thick and occurred in a quartz-rich sand sequence at depths of 90 to 120 m.

The results of this drilling program enhance the regional resource potential for Lower Cretaceous lignites. Additional reconnaissance drilling is warranted farther west, where little is known of the Mesozoic sequence. During winter 1983-1984, some additional drilling of this nature will be carried out as a continuation of the Lignite Assessment Project.

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TABLE 1 SUMMARY OF RESULTS, 1983 DRILLING PROGRAM (from unpublished report by Watts, Griffis and McOuat Limited, Toronto)

UNIT	83-01	83-02	83-03	83-04	83-05	83-06	83-07
Recent	2.1 m	1.9 m	2.4 m	4.3 m	6.1 m	28.1 m	2.5 m
Pleistocene	62.1 m	54.5 m	37.1 m	68.9 m	88.0 m	145.5 m	29.9 m
Cretaceous (Mattagami)	34.6 m	41.1 m	48.3 m	0.05 m	27.3+ m	6.3+ m	101.5 m
Jurassic (Mistuskwia Beds)	—	—	13.4+ m(?)	14.8 m(?)	—	—	—
Devonian	7.8+ m	9.2+ m	?	13.0+ m	—	—	12.2+ m
Total Depth	106.6 m	106.7 m	101.2 m	101.1 m	122.0 m	179.9 m	146.3 m

Geophysics/Geochemistry
Programs

Geophysical, Geochemical, and Geochronological Surveys and Research, 1983

R.B. Barlow[1]

Geophysical Program

During the 1983 summer field season, survey activity and experimentation continued on the Night Hawk geophysical test range near Timmins, Ontario. Several new techniques were applied specifically to help resolve conductors in close proximity, with encouraging results. The Night Hawk grid was extended 300 m east for the purpose of acquiring survey coverage over the eastern extension of the conductive zones outlined to date. A line traversing the midpoint of the conductive zones was widened to permit accurate navigation by airborne systems. In addition, an alternate test range in Sheraton Township has been prepared for survey work in the future. At least 3 known conductors in this area are covered by the new grid system.

Both the development and data acquistion stages of a contract to test-fly a commercial aeromagnetic gradiometer have been completed by Kenting Earth Sciences Limited of Ottawa. Approximately 19 000 line km of aeromagnetic data were acquired in September and October of 1983 in southeastern Ontario. A number of system tests were conducted in August for the purpose of benchmarking the signal-to-noise characteristics and the effectiveness of the compensation system. The results were impressive and demonstrated that the aeromagnetic gradiometer is now ready for commercial service.

An interpretation of the gravity data over the Sudbury area was completed over the summer season. The results are scheduled to be published in the "Ontario Geological Survey Special Volume on Sudbury". Eight profiles have been interpreted using 2 hypotheses with regard to the near-surface effects of the Sudbury structure. Modeling results have predicted the presence of a basic intrusion of larger areal extent at depth than the boundaries of equivalent surface rocks; this accounts for most of the 30 mGal gravity high in the area.

Geochemistry Program

An orientation geochemical survey, based on lake sediment sampling, has been completed in the Batchawana area between Sault Ste. Marie and the Montreal River, and serves as an essential preliminary study on which to base regional geochemical mapping of the area at a later date.

Six conceptual models have been developed to explain observations on multi-element stream sediment data acquired in Southwestern Ontario in previous years. A computer file has been generated for the purpose of accessing and interpreting the data.

The provision of information on the utility of geochemical exploration techniques form the basis for 2 studies presently underway. The first involves the synthesis and analysis of basal till geochemistry and mineralogy obtained during the Kirkland Lake Initiatives Program (KLIP), carried out in previous years in the Kirkland Lake area. The second involves field sampling completed for a small scale research project on the Williams claim under option to Lac Minerals Limited in the Hemlo area. The later has been designed as an interdisciplinary project involving input from both geochemistry and Quaternary geology for the purpose of investigating the overburden characteristics of gold, and associated pathfinder elements in the area of the ore deposit.

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[1] Chief, Geophysics/Geochemistry Section, Ontario Geological Survey, Toronto.

The research aspect of the geochemical program has involved further work in the Wawa area. This project was designed to examine the feasibility of adding an environmental component to future regional geochemical surveys which employ lake sediment sampling. In addition, sampling and analysis methods developed for the Wawa area are being tested in a small area to the north of Lake Wanapitei near Sudbury.

Geochronology Program

During the 1983 summer field season, a sampling program in 3 areas of Ontario involved the selection of rock specimens for both age determinations and investigation of zirconium content. Ten small samples from the Sault Ste. Marie-Batchawana area were collected from early volcanic rocks and spacially associated diabase dikes in the area. Eight samples for age dating were selected from the Madsen area and are closely related to lithologies hosting gold occurrences in that area. Four samples from an area west of Kenora at Keewatin were obtained for future age dating, and check samples were obtained from the Gordon Lake and Red Lake Road areas.

Results from 5 previous sampling programs were produced during 1983. In addition to standard dating procedures using the zircon U-Pb method, experiments were carried out using sphene mineral specimens obtained from some of the rocks collected. Preliminary results indicate that similar ages, or in some cases slightly younger ages, are observed when compared to the standard zircon U-Pb method.

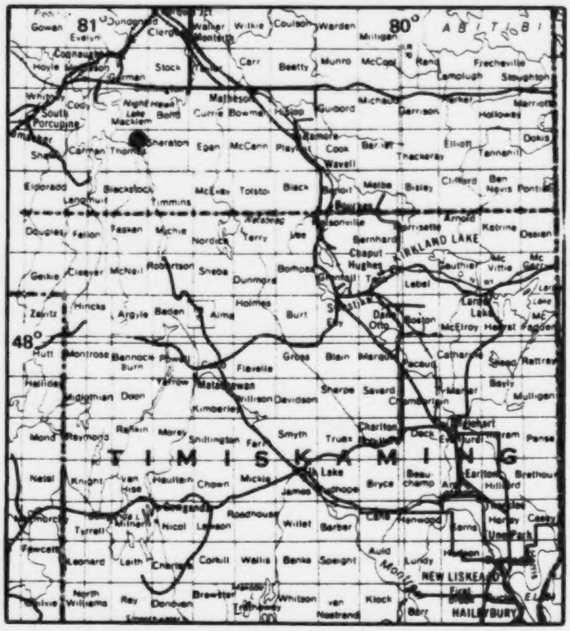
In the Favourable Lake area, 1 age date was added to complete a suite of 11 age dates in the area. A total of 12 age dates have now been produced from the Red Lake area. A quartz porphyry intrusion in the Madsen area has been dated at 2750 Ma. In the Batchawana area, 17 rock specimens show respective age ranges for volcanism of 2699 to 2710 Ma, and for plutonism of 2668 to 2717 Ma. A significant metamorphic event has been determined to have occurred about 2660 Ma. One age date from the Copper Cliff Rhyolite near Sudbury has been determined at 2450 Ma. At East Bow Lake, a gabbro intrusion and syenite, both previously thought to have intruded simultaneously, now show significant age differences of 175 Ma (2490 and 2665 Ma respectively). Farther to the east, at Agnew Lake, a sample of granophyre from a gabbroic intrusion shows an age of 2490 Ma.

No. 30 Night Hawk Geophysical Test Range Results, Night Hawk Lake, District of Cochrane

D.H. Pitcher[1], R.B. Barlow[2], and D.R. Wadge[3]

Introduction

During the 1983 summer field season and late fall of 1982, staff of the Geophysics/Geochemistry Section continued studies on a test range near Timmins, Ontario (Barlow 1981; Barlow, Pitcher, and Wadge 1982). The grid system, which was originally developed in 1981, covered an area of approximately 1 km² with 9 north-trending lines 100 m apart and 900 m in length with station pickets every 25 m along the lines. In an attempt to determine the eastern extent of predominantly east-trending bedrock conductors, the survey grid was extended 300 m to the east and the eastern lines were extended 100 to 200 m south. Also, Line 1 East has been cut approximately 3 m wide so that it can be located visually from the air for testing airborne systems.



LOCATION MAP

Scale: 1:1 584 000
or 1 inch to 25 miles

The test range program was initiated with the objective of developing certain areas, which are representative of exploration targets in Ontario, into sites for testing newly developed exploration technology. Sites that are selected for this purpose will be subject to ongoing tests using new geophysical equipment by Section staff and/or research scientists from university departments, industrial research and development groups, and staff scientists from the Geological Survey of Canada. The test ranges will therefore serve as field laboratories for geophysical research groups, thus aiding an important phase of exploration technology development. In addition, the sites will provide areas for instruction of field techniques in exploration geophysics.

The number of ground electromagnetic systems that have surveyed 1 or more lines at the test range is currently 6; including the MAXMIN III, pulse EM, and GENIE moving source systems, and EM-37, ELFAST, and cross-coil fixed source systems. Gravity, magnetic gradiometer, and elevation data have also been collected to provide complete coverage of the original grid and the grid extensions.

In addition to the work carried out by the Ontario Geological Survey, the Geological Survey of Canada has performed seismic and electromagnetic surveys, and the University of Toronto has performed audiofrequency magnetotelluric soundings. At least 3 different helicopter electromagnetic systems have traversed the survey grid; namely, Questor Surveys Limited, Aerodat Limited, and Dighem Limited. Also, the Geosurvey International Limited Scintrex Tridem system has flown the test range. Other companies that have utilized the grid for testing ground electromagnetic systems include Geonics Limited and Androtex Limited.

A second test range is presently being established by the Ontario Geological Survey in the northwestern quadrant of Sheraton Township. A metric grid consisting of 6 lines separated by 100 m and 1400 m in length was surveyed using transit and chaining techniques. The station picket separation was 25 m. The Sheraton Township test range was chosen as an alternate test site because of its close proximity to the Thomas Township test range and because of its different geological environment. The overburden in the vicinity of the Sheraton test area is indicated from drillholes to be variable in thickness, averaging at about 50 m, and consisting of sand, clay, and gravel. Preliminary surveying with the MAXMIN III utilizing a 200 m coil separation and the GENIE utilizing 50 m and 100 m coil separations, indicates a series of multiple bedrock conductors of poor to moderate conductance. Drilling by a number of mining companies indicates that the bedrock conductors in the area consist mainly of pyrite and graphitic tuffs.

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Location and Access

The Night Hawk Lake test range is located in the northeastern quadrant of Thomas Township approximately 12 km south of Highway 101, on Gibson Lake Road. The

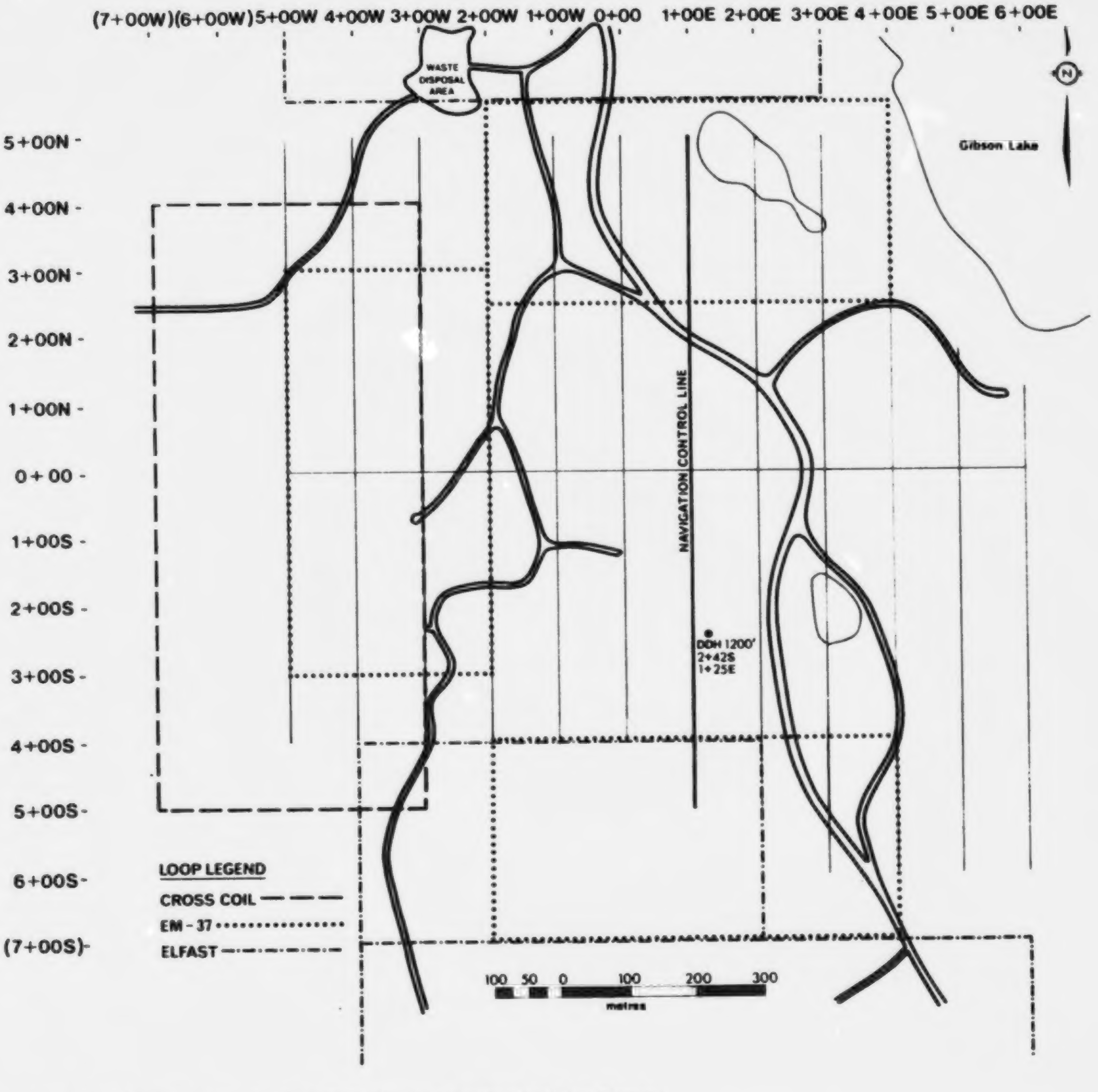
(7+00W)(6+00W)5+00W 4+00W 3+00W 2+00W 1+00W 0+00 1+00E 2+00E 3+00E 4+00E 5+00E 6+00E
N
WASTE DISPOSAL AREA
Gibson Lake
5+00N
4+00N
3+00N
2+00N
1+00N
0+00
1+00S
2+00S
3+00S
4+00S
5+00S
6+00S
(7+00S)
NAVIGATION CONTROL LINE
DDH 1200'
2+42S
1+25E
LOOP LEGEND
CROSS COIL
EM-37
ELFAST
100 50 0 100 200 300
metres

Figure 1. Grid location map for the Night Hawk Geophysical Test Range.

Gibson Lake Road turnoff is located approximately 40 km east on Highway 101 from Timmins, Ontario.

Figure 1, illustrating the grid, large transmitter loops, a previous drillhole, the navigation control line, and access roads, shows that few areas of the grid are without ready access by vehicle.

Moving Source Ground Electromagnetic Systems

GENIE Data—Frequency Domain

An in-line SE-88 GENIE portable electromagnetic system was utilized over the entire survey grid from 5 West to 6 East using a separation of 100 m between the transmitter and receiver. Lines 1 East, 2 East, and 0 were surveyed using a coil separation of 150 m. The effect of coil separation was further investigated by also traversing Line 1 East employing coil separations of 50, 75, and 125 m.

The GENIE, an acronym for Geometry Normalized Electromagnetic system, employs the horizontal coplanar coil configuration with the axes of 2 iron-cored transmitting coils and a single receiver coil being in the vertical direction. Two pre-selected, amplitude stabilized, well separated frequencies are transmitted simultaneously and picked up by a single receiver coil. The computed result $(V_{signal}/V_{reference} - 1) \times 100$ is displayed on the digital display, where V_{signal} and $V_{reference}$ are proportional to the received amplitude of the higher and lower transmitted frequency, respectively.

Since the amplitude measurements are normalized to a lower frequency reference signal, no interconnecting cable is required between the transmitter and receiver operators, thereby adding to the portability of the system. Automatic normalization to a lower transmitted frequency also minimizes errors due to improper coil orientation.

Particularly in resistive environments, the lowest transmitted frequency is relatively unaffected by earth conductivity. Its amplitude, which is displayed on a calibrated analogue meter at the receiver, is a function of transmitter-receiver separation. The operator can adjust his position to ensure that the proper separation is maintained.

Multi-frequency information is obtained over a wide range of frequencies by transmitting 5 different frequency pairs as summarized in Table 1. The transmitting moments are presented in Table 2.

TABLE 1 TRANSMITTING FREQUENCY PAIRS FOR THE GENIE

REFERENCE (Hz)	SIGNAL (Hz)
112.5	337.5
112.5	1012.5
112.5	3037.5
337.5	1012.5
337.5	3037.5

TABLE 2 TRANSMITTER OUTPUT FOR THE GENIE

FREQUENCY (Hz)	DIPOLE MOMENT (A.m^2)
112.5	150
337.5	100
1012.5	50
3037.5	25

The GENIE data for Line 1 East for separations of 75, 100, and 125 m are presented in Figure 2. It should be noted that the anomaly shape of the GENIE system to a steeply dipping thin plate conductor is the same as that observed with the standard slingram (horizontal loop system); namely, a negative response directly over the current axis of the plate. The data in Figure 2 indicate a positive sign anomaly in the vicinity of stations 1 + 75 South to the Base Line, which is best defined at frequency pairs 337/112 and 1012/112 Hz, indicating a flat lying or wide conductor. This "reverse sign" anomaly is consistent with the 100 m separation PEM data (Barlow, Pitcher, and Wadge 1982). An alternative interpretation may be the synclinal fold model (Barlow, Pitcher, and Wadge 1982), which is represented by 2 conducting plates dipping toward each other in the vicinity of 0 + 25 North and 1 + 50 South, although detailed multiple conductor modelling is required to confirm whether this model fits the observed GENIE data.

MAXMIN III Data—Frequency Domain

Extensive coverage of the grid has been obtained using the MAXMIN III slingram (horizontal loop) system. The coverage obtained this year and reported in previous years is summarized in Table 3.

The maximum coupled mode 1983 data is presented in Figure 3. It should be noted that Line 1 East for the 150 m coil separation presented by Barlow, Pitcher, and Wadge (1982) was resurveyed due to measurement errors and the corrected results are shown in Figure 3. The generally noisy in-phase profile for the 100 m data is most likely due to slight errors in coil separation and perhaps orientation, which are critical with this system at the shorter separations. For example, a 1 m error produces a 3% in-phase error employing a 100 m separation due to the inverse cube law of attentuation of the primary magnetic field. Hence, this line may be resurveyed using greater emphasis on maintaining exact coil separation and orientation.

PEM Data—Time Domain

The in-line PEM data coverage to date has been reported by Barlow, Pitcher, and Wadge (1982); namely, Lines 2 West to 3 East using a 100 m coil separation.

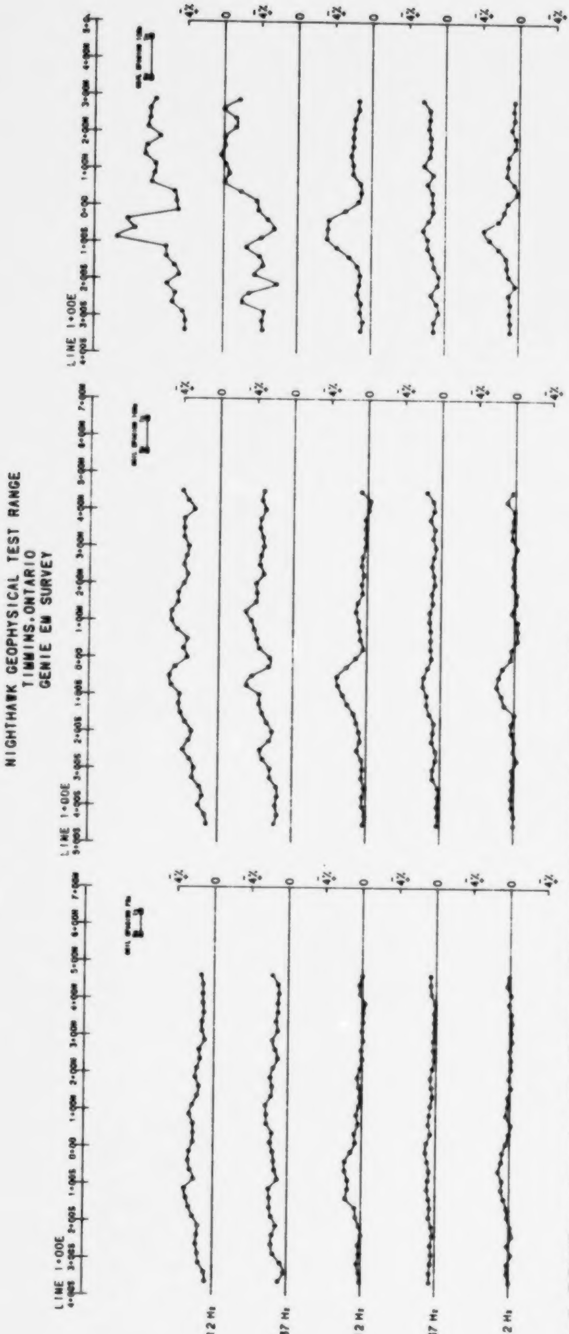

Figure 2. GENIE results using 75, 100, and 125 m coil separations over Line 1 East.

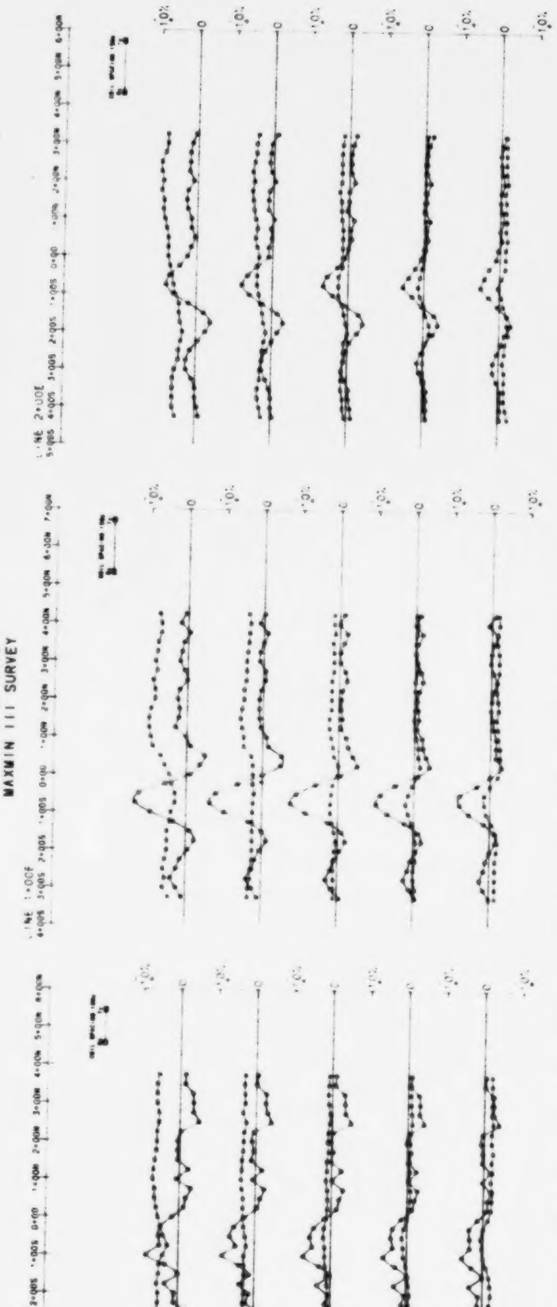

Figure 3. MAXMIN III results using a 100 m coil separation over Line 1 East, and a 150 m coil separation over Lines 1 East and 2 East.

TABLE 3 MAXMIN III SURVEY COVERAGE

LINES	MODE	COIL SEPARATION (m)	YEAR SURVEYED (m)
5 West – 3 East	Max	200	1981
2 West – 1 East	Max & Min	150	1982
1 West – 1 East	Max & Min	250	1982
1 East	Max & Min	100	1983
1 East – 2 East	Max & Min	150	1983

Fixed Source Ground Electromagnetic Systems

ELFAST Data—Frequency Domain

ELFAST (Extra Low Frequency Automatic Scanning Turam) is a fixed source electromagnetic method based on the standard Turam principle. A detailed description of the Turam method is presented by Bosschart (1964). The Turam method employs a large, generally rectangular transmitting loop, through which an alternating current flows. A number of survey lines are traversed perpendicular to the long side of the loop using 2 receiver coils separated by distances of 25 to 200 m. Measurements of the absolute field strength at each coil and the phase difference between the received field at each coil are taken.

The Turam method has been traditionally used in areas that require a considerable depth of exploration, and in areas with topographic relief because of its relative immunity from topographic effects. Multi-frequency information is obtained with the ELFAST version of Turam at 25, 75, 225, 675, and 2025 Hz, using an automatic scanning system with which the receiver can be synchronized. This facility eliminates the requirement for an operator at the transmitter having a communications link with the receiver.

The maximum output power of the transmitter is 500 watts, while the maximum output current is 5 A. The output current waveform is a square wave.

The standard survey configuration for the Turam technique consists of placing a rectangular loop with the long side of the rectangle approximately parallel to the strike of the bedrock conductors. A number of survey lines are then traversed perpendicular to the geological strike. Three different loop layouts were employed, using a receiver coil separation of 50 m, for the ELFAST results along Line 1 East presented in Figure 4. The loop locations are summarized in Table 4 and the current levels for each loop are presented in Table 5.

It should be noted that all the measured and derived parameters in Figure 4 are independent of current level. A list of the plotted parameters includes:

1. Reduced Field Strength Ratio—observed field strength ratio V_1/V_2 normalized by the calculated primary field strength ratio
2. Phase difference—measured phase gradient between the received fields at coil 1 and coil 2
3. Reduced Secondary Field Difference—smoothed horizontal derivative of the secondary field normalized to the local primary field in percent
4. Reduced In-phase Field—smoothed horizontal derivative of the in-phase component of the secondary field normalized to the local primary field in percent using the accumulated phase
5. Reduced Quadrature Field—smoothed horizontal derivative of the quadrature component of the secondary field normalized to the local primary field in percent using the accumulated phase

These profiles indicate the presence of 2 major conductive zones in the vicinity of 1 + 25 to 1 + 50 South and 0 + 25 North. ELFAST resolves both conductors with either north or south loops, particularly at high frequency. This resolution is most likely due to the nature of the gradient measurement attained with Turam. From previous drilling results, the overburden depth is approximately 87 m while the separation of the conductors has been interpreted to be in excess of 150 m. Bays, Duckworth, and Rogozinski (1983) state that their modelling results indicate the ability of Turam to resolve multiple targets, provided their separation is greater than their depth which appears to be true in the present situation.

Cross-coil Data—Frequency Domain

The cross-coil system (A.B. Fleming, Geophysical Contractor, Toronto, Ontario, personal communication, 1983) is a frequency domain fixed source method. The transmitting loop is placed on strike with the zones of anomalous conduction. For the present test survey, the loop was centred at 5 West, 0 + 50 South, while traversing Lines 1 West to 3 East. This loop configuration has the advantage of improved resolution of multiple conductors, which has also been tested using the Turam method (Bays, Duckworth, and Rogozinski 1983).

The received field is measured with 2 orthogonal coils (hence, the name cross-coil) oriented in a direction such that the horizontal and vertical components of the secondary field may be resolved mathematically as well as the absolute phase angle between the secondary and primary field. Also, the plane of the coils is oriented in an attempt to minimize the contribution due to background

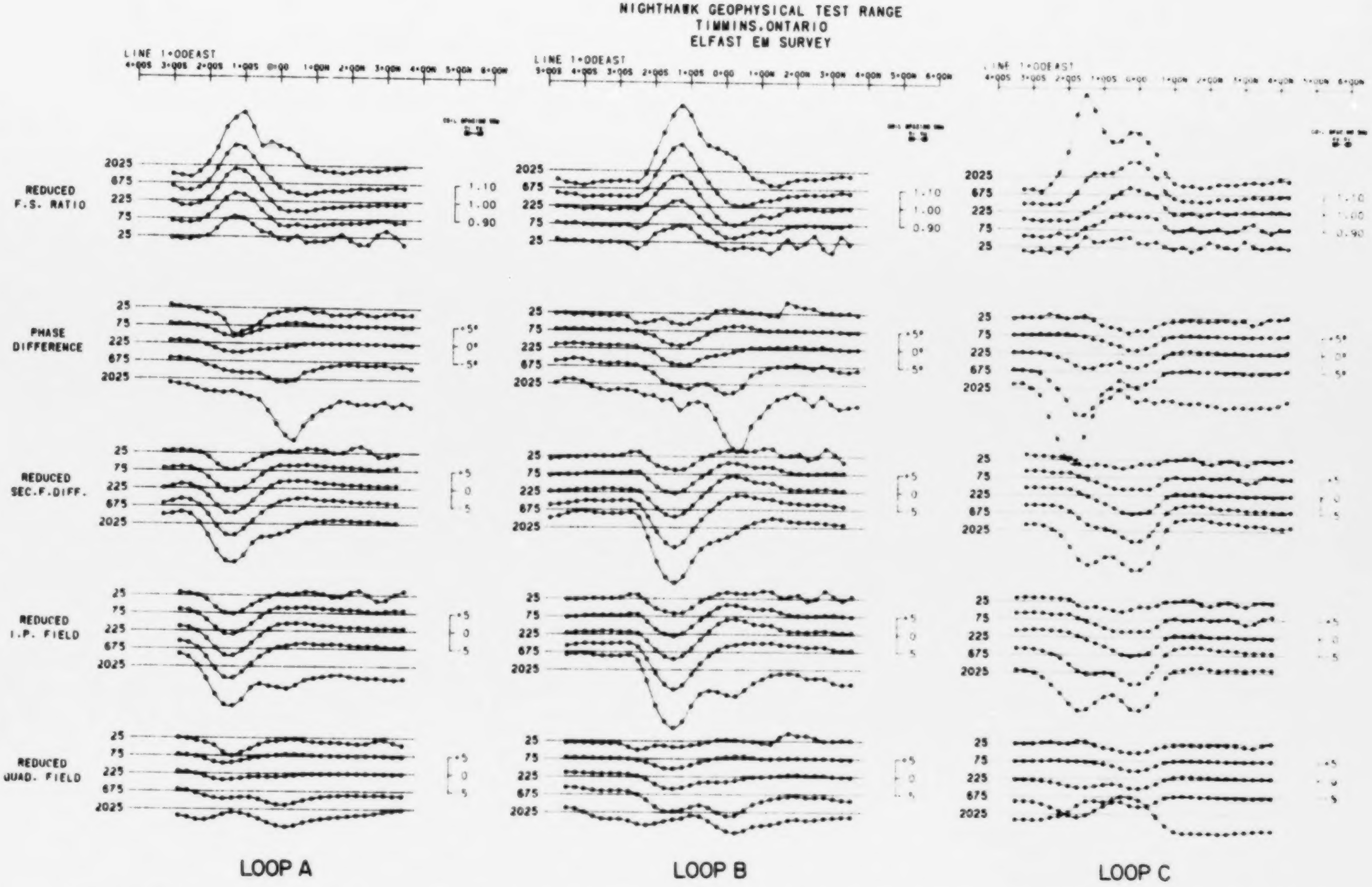

Figure 4. ELFAST results using 3 different transmitter loops (South Loops A and B, North Loop C) and a receiver coil separation of 50 m over Line 1 East

TABLE 4 ELFAST TRANSMITTER LOOP LOCATIONS

LOOP NAME	CENTRE	SIZE
A – South Loop	(1 West, 5 + 50 South)	300 by 600 m
B – South Loop	(1 East, 9 + 50 South)	500 by 1000 m
C – North Loop	(1 West, 8 + 00 North)	500 by 800 m

EM effects caused by conducting overburden and host rock.

The instrumentation for the current survey involved the standard ELFAST transmitter with a pair of receiver coils mounted on a tripod. A modified ELFAST receiver measured the amplitudes and phase differences of the received fields at the receiver coils. A summary of the parameters presented in Figure 5 for Line 1 East includes:

1. Measured Field Ratio—ratio of magnetic field amplitudes received with each coil
2. Measured Phase Difference—phase difference between the 2 received fields
3. Absolute Phase Difference—computed phase difference between the secondary and primary field
4. Secondary Horizontal Field—computed secondary horizontal field in the direction of the horizontal orientation of the coils
5. Secondary Maximum Horizontal Field—computed maximum horizontal field based on the estimated strike of the anomalous zones of conduction
6. Secondary Vertical Field—computed secondary vertical field

A preliminary analysis of this data shows that 2 current axes, of opposite polarity, are clearly resolved at 0 + 25 North and 1 + 75 South.

EM-37 Data—Time Domain

This year, extensive coverage of the survey grid was achieved with the EM-37 system. Three different 300 by 600 m loop configurations were employed and a summary is presented in Table 6.

Some of these lines were surveyed during previous field seasons; however, the present results were achieved using approximately twice the transmitted current level,

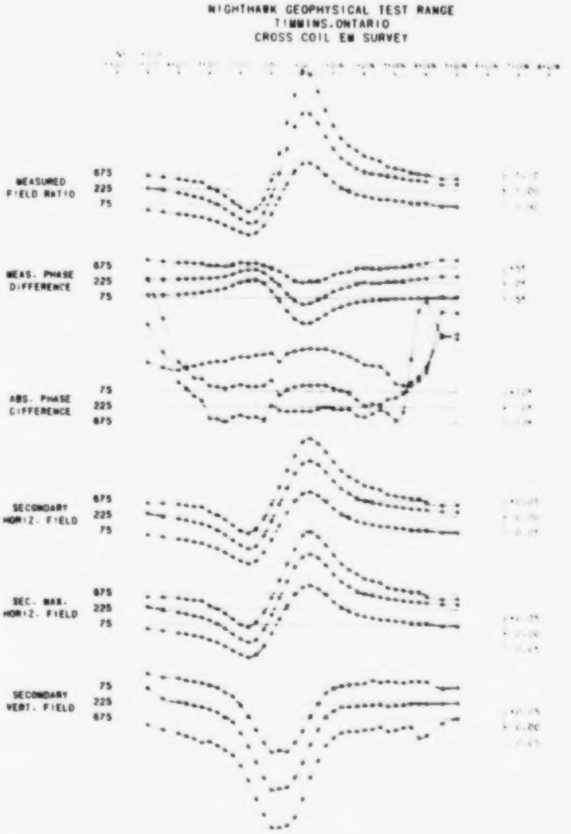

Figure 5. Cross-coil results over Line 1 East using west loop.

TABLE 5 ELFAST TRANSMITTER CURRENT LEVELS

FREQUENCY (Hz)	CURRENT LOOP – A (A)	CURRENT LOOP – B (A)	CURRENT LOOP – C (A)
25	3.44	2.77	3.11
75	3.37	2.71	3.05
225	3.15	2.53	2.85
675	2.45	1.97	2.24
2025	1.00	0.84	0.97

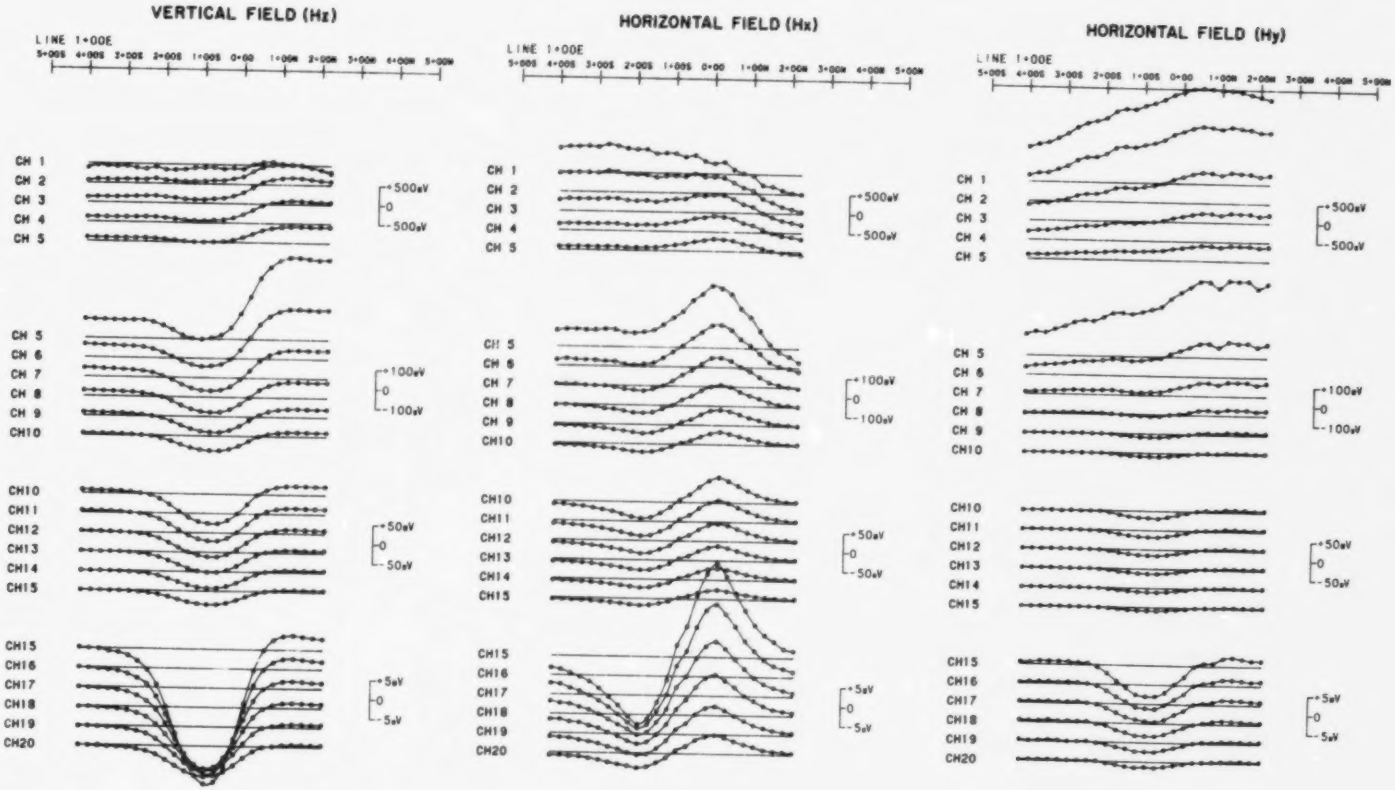

Figure 6. EM-37 results over Line 1 East using west loop.

TABLE 6 **1983 EM-37 LOOP LOCATIONS AND COVERAGE**

LOOP NAME	LOOP CENTRE	COVERAGE
South Loop	(1 + 00 East, 5 + 50 South)	2 West - 4 East
North Loop	(1 + 00 East, 4 + 00 North)	2 West - 4 East
West Loop	(3 + 50 West, 0 + 00)	1 West - 1 East

30 A, and hence the dipole moment of the transmitter loop was increased to 5.4×10^6 A . m^2. The fundamental frequency of the transmitted signal was 30 Hz and the turn off time was 470 µs. Twenty channels of information were obtained for 3 orthogonal coil configurations using the gate centres and widths as summarized in Table 7. It should be noted that these are slightly different than the gate centres and widths presented in Table 1 (Barlow 1981), due to circuit modifications.

The data collected along Line 1 + 00 East employing the west loop is presented in Figure 6. It should be noted that the horizontal field, Hx, is the component along the survey line, and Hy is perpendicular to the line. These results are consistent with the corresponding cross-coil results (Figure 5); namely, current axes of opposite polarity are defined at 1 + 75 South and 0 + 25 North.

TABLE 7 **EM-37 GATE CENTRES AND WIDTHS FOR SAMPLING CHANNELS**

CHANNEL	GATE CENTRE (µ s)	GATE WIDTH (µ s)
1	87	18
2	107	24
3	137	36
4	174	35
5	216	49
6	274	71
7	348	75
8	434	98
9	552	139
10	698	153
11	859	176
12	1065	245
13	1372	372
14	1737	382
15	2166	490
16	2764	706
17	3499	764
18	4371	1058
19	5554	1392
20	7017	1529

Future Activities

Some additional experiments are planned for next year on the Night Hawk test grid. As well, an effort will be made in the future to complete basic survey coverage over the Sheraton test grid with some experimentation. A continuous effort will be made to develop computer storage and retrieval systems as well as computer interpretation techniques for field portable microcomputers.

An interpretation and synthesis of data acquired to date has been initiated. This will be completed in the near future and published in the form of an Open File Report.

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No. S31 Test Surveys and Developments in Aeromagnetic Gradiometry

R.B. Barlow[1]

THIS PROJECT IS PART OF THE SOUTHEASTERN ONTARIO GEOLOGICAL SURVEY (SOGS) WHICH WAS FUNDED EQUALLY BY THE FEDERAL DEPARTMENT OF REGIONAL ECONOMIC EXPANSION (DREE) AND THE ONTARIO MINISTRY OF NATURAL RESOURCES UNDER THE MINERALS PROGRAM OF THE EASTERN ONTARIO SUBSIDIARY AGREEMENT.

INTRODUCTION

Over the past 2-year period, Kenting Earth Sciences Limited of Ottawa received funding under contract to develop a commercial aeromagnetic gradiometer system, and to complete 2 test areas, both located in southeastern Ontario. The development project was administered by the Geophysics/Geochemistry Section, with continuous technical assistance from the Resource Geophysics and Geochemistry Division of the Geological Survey of Canada and the consulting firm of Paterson, Grant, and Watson Limited, Toronto.

The general objective of this program was to encourage the development of a "commercial" aeromagnetic gradiometer capable of measuring the vertical difference of the magnetic field, over a fixed interval, comparable to previous standards of achievement accomplished by the Geological Survey of Canada.

The funds necessary to provide adequate test survey results were advanced periodically over the development period to help defer interest on the capital expenditures, and to demonstrate scientific interest and recognition of the mapping capabilities of such a system with respect to near-surface geology. The test areas were selected on the basis of stratigraphic complexity in order that the resolution of the system, and hence the mapping capabilities, could be demonstrated over Precambrian terrain.

In addition to the Kenting gradiometer, we have sponsored some of the development work of comparable equipment developed by Questor Surveys Limited. The results of tests conducted with Questor are reported by Lechow (1983).

Location

The 2 test survey areas are located near the municipalities of Kaladar and Marmora in southeastern Ontario (Figure 1). Approximately 19 000 line km were flown in September and October, 1983, at a mean terrain clearance of 150 m and with a flight line spacing of 200 m. The areas are outlined in Figure 1 together with the outline of the map-sheet layout.

Description of General Specifications

Several important features pertaining to the mapping sensitivity of the thin, high angle, stratigraphic units generally encountered in Precambrian terrain were incorporated into the basic design specifications.

Two single-cell self-orienting optical absorption magnetometers, manufactured by Varian (Canada) Limited, measure differences in the earth's magnetic field simultaneously with a sensitivity of ±0.005 gammas/m. The twin inboard booms containing the magnetic sensors are separated by a 2 m vertical distance. The configuration shown in Figure 2 features a novel retractable lower boom which is necessary in this case for safe runway operations. Both the sensitivity of the magnetometers and the separation are important factors which control the resolution of the amplitude of gradient signatures.

The horizontal resolution on the other hand is a function of aircraft speed and data acquisition rate. The digital acquisition system is software-controlled to systematically sample the total magnetic field at each level of the 2 sensors every 0.25 seconds. Assuming the average ground speed of the Piper PA-31 Navajo aircraft to be in the neighbourhood of 135 knots (69.45 m/second), the data acquisition rate will correspond to 1 sample every 17.4 m on the ground. If 5 samples are considered the minimum number necessary to describe a gradient signature, then gradient anomalies having a horizontal extent of 87 m in the direction of flight at the 150 m flight altitude can be fully resolved.

The noise levels of the magnetic sensors are monitored in-flight, and determined by fourth difference calculations. Total fields, vertical gradient, and respective fourth differences are displayed in stacked format on an analogue chart recorder. The noise levels as determined by the fourth difference filter, in tests conducted to date, indicate that the degree of the turbulance registered on the structure of the airframe at survey altitude can be recog-

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[1] Chief, Geophysics/Geochemistry Section, Ontario Geological Survey, Toronto.

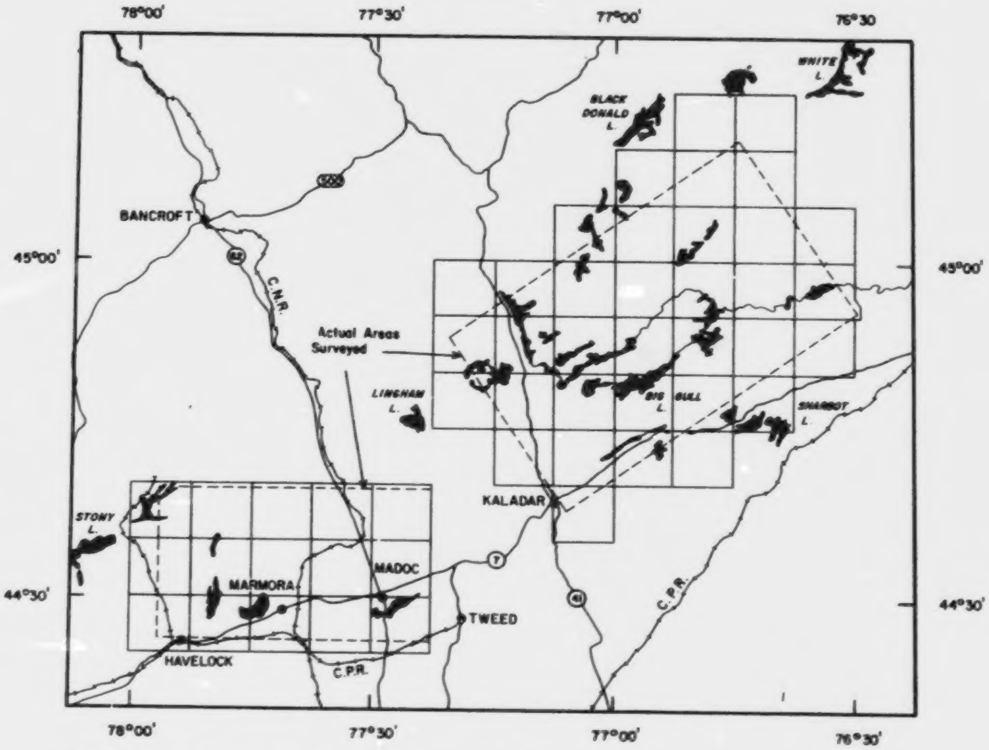
78°00'
77°30'
77°00'
76°30
BLACK DONALD L.
WHITE L.
500
BANCROFT
45°00'
45°00'
62
C.N.R.
Actual Areas Surveyed
LINGHAM L.
BIG GULL L.
SHARBOT L.
KALADAR
STONY L.
7
MADOC
MARMORA
41
C.P.R.
44°30'
44°30'
TWEED
HAVELOCK
C.P.R.
78°00'
77°30'
77°00'
76°30'

Figure 1. Test survey locations with the outlines of the map sheets.

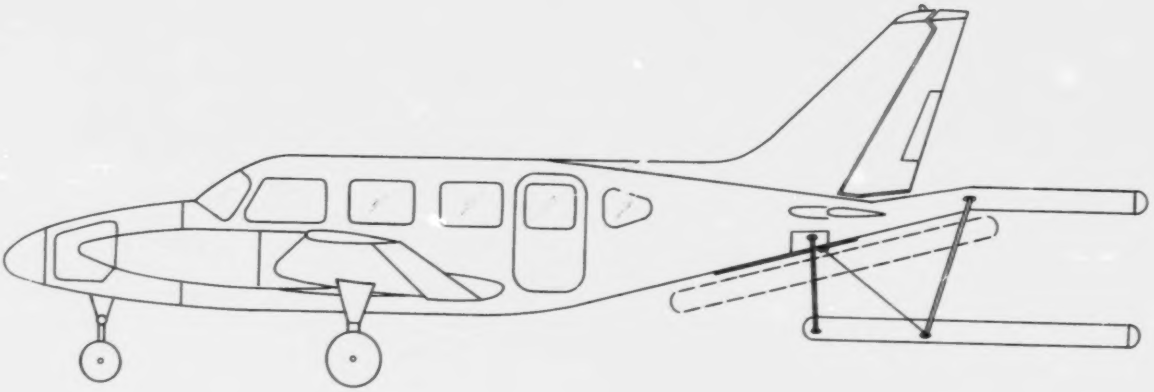

Figure 2. An illustration of the Piper PA-31 Navajo aircraft modification for aeromagnetometer gradiometer surveying. A retractable lower boom allows a separation of 2 m and permits safe runway operation.

nized and used as a direct criteria for determining exceptable data on a real time basis. During acceptable flight conditions, the fourth difference noise swath does not exceed 0.02 gammas and 0.025 gammas/m for the total field and vertical gradient respectively, with the exception of infrequent short bursts of fourth difference activity which are due to turbulance or geological noise (undersampling).

A magnetic compensation "Figure of Merit" (FOM) should not exceed 1 gamma on either sensor, and the combined FOM index for the 2 sensors in their difference output should not exceed 2 gammas. This index is obtained by summing without regard to sign, the peak-to-peak amplitudes of the 12 residual magnetic signatures recorded when the aircraft carries out repeated 20° rolls (peak-to-peak, i.e. ±10°), 10° pitches (peak-to-peak, i.e. ±5°), and 10° yaws (peak-to-peak i.e. ±5°) over periods of 4 to 5 seconds in flight. The effect of the changing position of magnetic field due to the aircraft itself is removed in large part by employing a 9 term compensator which is manufactured by CAE Limited of Montreal. The FOM is a measure of the residual effects not removed and thus a measure of the effectiveness of the compensation system after calibration.

An average line spacing of 200 m is specified for the test surveys. Spacings (gaps) of greater than 300 m between flight lines over distances greater than 5 km require fill-in data. Also, absolute separations between adjacent lines were specified not to exceed 400 m or be within 50 m of an adjacent line. The control of fundamentals such as line spacing become the critical factor when gridding and contouring the data.

Summary

Initial testing of the Kenting gradiometer system has been completed. As well, 2 test areas in southeastern Ontario are in the final completion stage and the results are expected to be released in 1984. Specifications for conducting the test surveys are severe when compared to standards normally accepted in industry. The results of the test surveys should prove to be a useful benchmark with regard to aeromagnetic mapping capability in Precambrian terrain.

Reference

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No. 32 On The Sudbury Gravity Anomaly

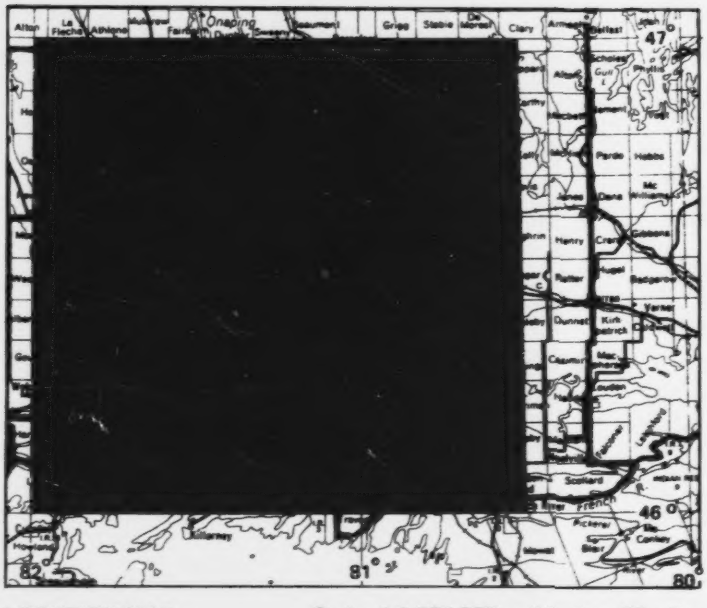
V.K. Gupta[1]

Introduction

An interpretation of the gravity data over the Sudbury area was undertaken in early 1983, as a contribution to the "Ontario Geological Survey Special Volume on Sudbury" geology. The gravity survey in this area was initially carried out by the Earth Physics Branch of the Department of Energy, Mines and Resources, Canada (Popelar 1972). During the past few years, Ontario Geological Survey field parties have also established gravity stations immediately to the north and east of the Sudbury Intrusive Complex. Both the Earth Physics Branch and Ontario Geological Survey data were combined and gridded at 1 km intervals in both the north-south and east-west directions. The resultant Bouguer gravity map of the Sudbury area is shown in Figure 1.

Anomaly Description

The elliptical Bouguer gravity anomaly of about +30 mGal amplitude is coincident with the Sudbury Intrusive Complex. This elliptical anomaly occurs near the northern flank of a large positive east-northeast-trending gravity signature that forms part of a chain of gravity "highs" extending from the Elliot Lake area through Sudbury and Lake Temagami to Englehart, a distance of nearly 350 km. As evident from Figure 1, the surface geological expression of the Sudbury Structure does not lie at the centre of the elliptical gravity "high", rather, its axis is offset to the north of the gravity axis by about 8 to 10 km. Also, the gravity anomaly is much broader than the surface expression of the Sudbury Structure and extends well beyond its boundaries. This leads to a suggestion that the gravity anomaly and the Sudbury Structure are not directly related. We believe that the Sudbury Structure produces a relatively small gravity effect which is superimposed upon the main anomaly caused by deep-seated sources. However, it is not immediately evident from the



LOCATION MAP Scale: 1:1 584 000 or 1 inch to 25 miles

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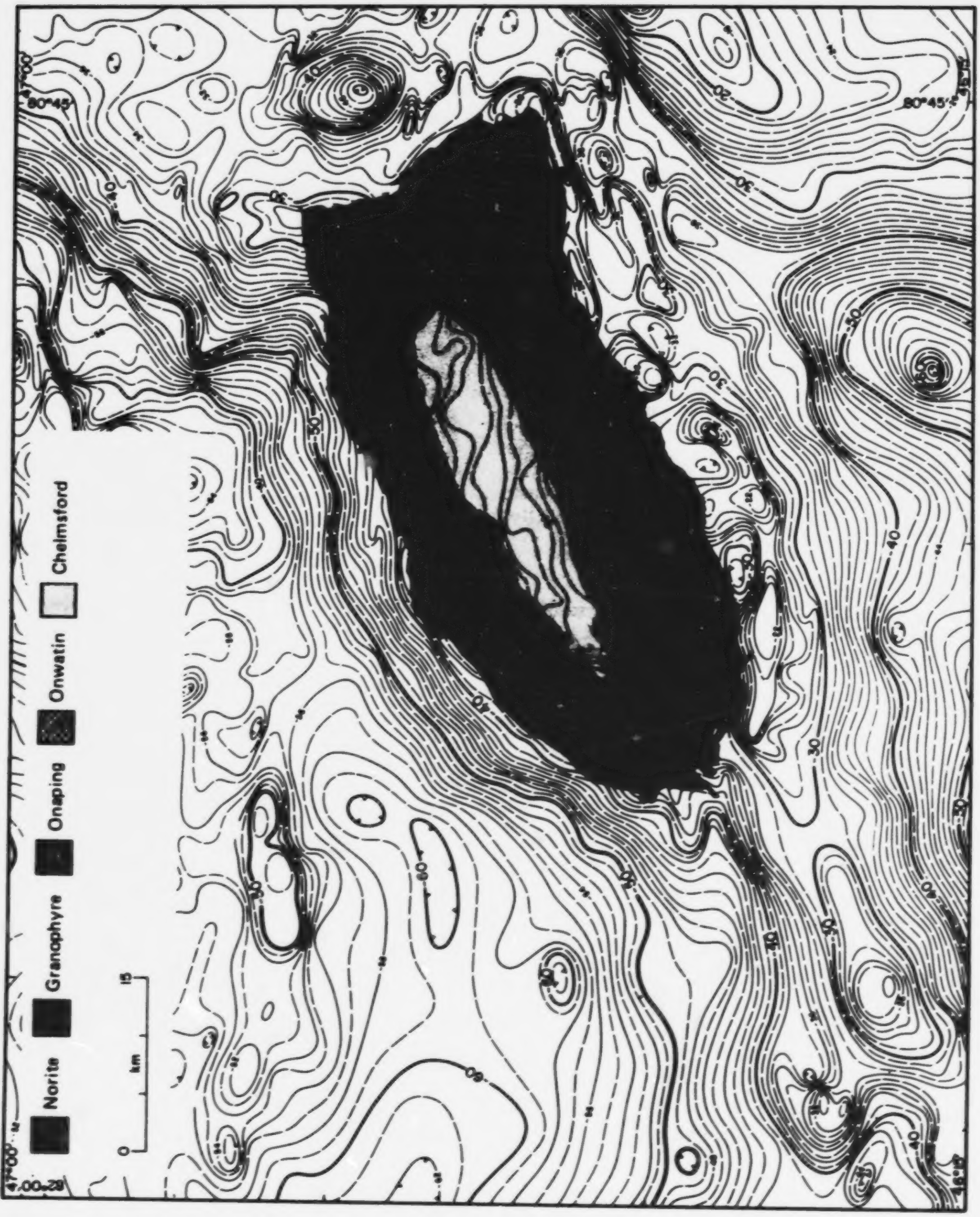
[1] Geophysicist, Geophysics/Geochemistry Section, Ontario Geological Survey, Toronto.


Norite
Granophyre
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km
15
80°45'
47°00'
30
40
50
60

Figure 1 Bouguer gravity field of the Sudbury area Contour interval is 1 milligal

Bouguer gravity contours (Figure 1) whether this effect is negative or neutral, relative to the regional gravity field. The surface densities of the rock units present in the Sudbury Basin indicate that the near-surface gravity effect, on a volume basis, would have a neutral to slightly negative gravity effect compared to the regional background. The answer lies in the separation of the Bouguer gravity field into its regional and residual components.

By regional-residual separation of the Bouguer gravity field, several levels of regional and residual maps were obtained by the process of graphical separation. Two hypotheses were chosen for the separation process:

1. Gravitationally Negative Sudbury Structure: that the rocks of the Sudbury Structure are less dense on the average than the surrounding gneissic and metasedimentary formations, producing a negative gravity effect
2. Gravitationally Neutral Sudbury Structure: that the rocks of the Sudbury Structure have the same average density as the surrounding gneissic and metasedimentary formations, producing no gravity effect

For each hypothesis, 2½-Dimension interactive gravity modelling by "least square" inversion was carried out on 8 profiles

Previous Work

A 3-dimensional gravity interpretation of the Sudbury area was previously reported by Popelar (1972). The need to reinterpret arises from the fact that beneath the Sudbury area, Popelar assumed a crust extending to a depth of more than 10 km with an average density of 2.65 g/cm^3. This suggests that 2.65 g/cm^3 is the average density of the Superior crust over a wide area to the north, east, and west of the Sudbury Structure. This implied assumption by Popelar is doubtful due to the following reasons:

1. A mean density of 2.75 g/cm^3 and a weighted mean density of 2.73 g/cm^3 has been computed from over 3400 rock density measurements on surface samples taken by the Ontario Geological Survey (between Latitudes 46°15′N and 48°N, and west of the Quebec boundary to Longitude 82°W; Gupta *et al.* 1981).
2. According to the gravity models of Popelar (1972), the Superior Crust ($\bar{\rho} = 2.65$ g/cm^3) is less dense than the Grenville Crust ($\bar{\rho} = 2.73$ g/cm^3). If this is true, then both the isostatic and the Bouguer gravity fields would be generally lower in the Superior Province than in the Grenville Province. However, this is not the case.

Popelar (1972) has introduced a thin layer of Levack gneiss complex ($\bar{\rho} = 2.73$ g/cm^3) underlying the norite ($\bar{\rho} = 2.83$ g/cm^3) of the Sudbury Intrusive Complex, and overlying the granitoid rocks ($\bar{\rho} = 2.65$ g/cm^3). This results in Popelar modelling a 9 km thick Levack gneiss complex on the northern side of the Sudbury Intrusive Complex. We consider this concept a bit artificial and can be avoided by choosing a correct background density.

Summary of Interpretation

The following is a brief description of the Sudbury Bouguer gravity anomaly:

1. The Sudbury Structure occurs within a positive gravity anomaly that is a member of a continuous chain of anomalies extending along an arc over a distance of nearly 350 km from Elliot Lake to Englehart via Sudbury.
2. The Sudbury gravity anomaly extends well outside the borders of the Sudbury Intrusive Complex.
3. The Sudbury Structure is underlain by a massive sill-like body of mafic to ultramafic composition that is thought to be a large, layered intrusion.
4. The sill-like mass has a thickness of about 3 km and lies at a depth between 5 to 8 km, with a probable average depth of about 6 km.

It is suggested that the Sudbury Structure may have been formed by a major collapse following a comparatively sudden increase in volume, caused by serpentinization, of some of the rocks contained within the underlying sill-like mass.

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No. 33 Detailed Element Abundance/Diatom Inferred pH Relationships for the Collection of Mineral Exploration/Environmental Information from Lakes in the Vicinity of Wawa, District of Algoma

John A.C. Fortescue[1]

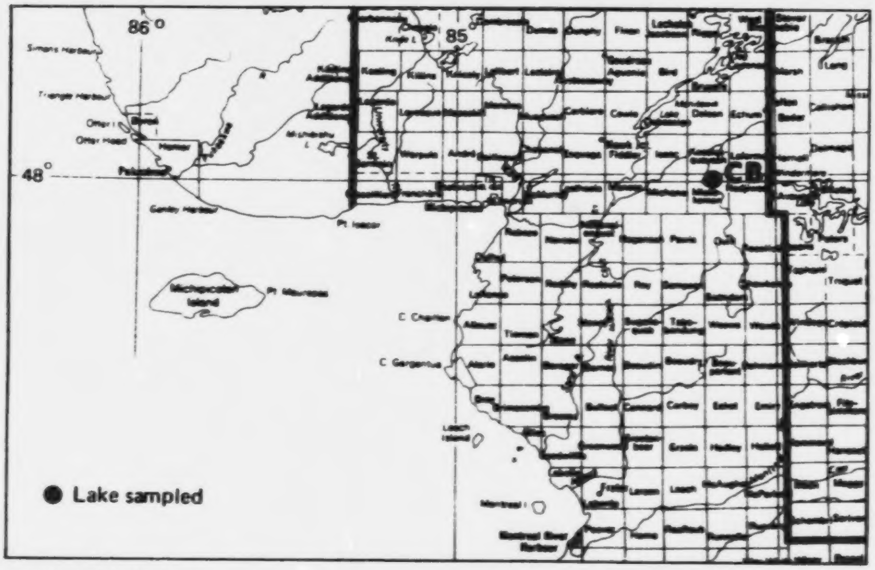
Introduction

During 1983, research was concluded on lakes in the vicinity of Wawa, which had been studied by an interdisciplinary team in 1980, 1981, and 1982 (Thomson 1980; Fortescue *et al.* 1981; Thomson 1981; Fortescue *et al.* 1982; Fortescue *et al.* in press). The research has investigated, in detail, relationships between the abundance geochemistry and limnology of 50 lakes in relation to the problem of acid precipitation, and provided a firm basis for the incorporation of an environmental component in future regional geochemical surveys completed for mineral resource appraisal purposes.

The interdisciplinary team established that lake sediment cores collected from lakes in the Wawa area can provide information on the sedimentation rate in the lake during the past 100 years. Such information is based on the "*Ambrosia* rise", which is a palynological marker, and other limnological markers. In general the sediment laid down during the past 100 years is usually between 7 and 15 cm below the present water-sediment interface at the bottom of the lake.

Another aspect of the research was to establish that the post *Ambrosia* pH history of a lake can be inferred from the relative abundance of numerous diatom species in subsamples of lake sediment cores taken at 1 or 0.5 cm intervals. This research was completed by Professor M. Dickman and his co-workers at Brock University, St. Catharines, Ontario.

The abundance of chemical elements in lake sediment



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

cores in post *Ambrosia* time has also been studied in some detail in the Wawa material (Fortescue *et al.* 1981; Fortescue *et al.* in press).

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The aim of the research described here was to discover relationships between the abundance of 1, or more, chemical elements in post *Ambrosia* sediment material, and the diatom inferred pH information obtained from the same core. A clearly defined relationship of this type would allow for the rapid scanning of lake sediment core abundance geochemical data for signs of the effect of acid precipitation in order to discover which lakes included in a regional geochemical survey should be subjected to further environmental study.

Objectives

The objectives of this project are:

1. to develop a technique for the routine study of details of the abundance geochemistry of lake sediment core material laid down in post *Ambrosia* time
2. using diatom inferred pH information, discover if abundance patterns in the post *Ambrosia* geochemical data relate directly to changes in the pH of waters due to acid precipitation or some natural cause

Methodology

Details of the palynology, limnology, and geochemical methodology applied in the interdisciplinary Wawa lakes study have already been described (Fortescue *et al.* 1981; Fortescue *et al.* in press). Briefly, lake sediment cores were collected using a gravity corer. Later the same day, cores were extruded using a device designed by M. Dickman which allows for 0.5 cm segments of the top part (i.e. post *Ambrosia*) of the core to be taken. A small sub sample from each sample was taken for palynological and diatom study and the rest used for chemical analysis. Prior to chemical analysis for Al, Ca, Mg, Fe, Mn, Ba, K, Pb, and Zn, the sediment was freeze-dried under strict quality control conditions. The resulting chemical data was normalized using KK values (i.e. Clarkes) listed by Ronov and Yaroshevski (1972). The data was then graphed to facilitate element to element and core to core comparisons (Figure 1).

Preliminary Results

The detailed study involved cores from 8 lakes, 2 of which are discussed here. Figure 1 gives some idea of the 'within core' element to element abundance relationships, and the lake to lake relationships for the 10 elements. In general, the agreement of the patterns is good in spite of sampling and analytical errors which are always present in data of this type. In general, all elements behave similarly (except for lead and zinc), which might be expected because both lakes are situated within the same catchment area. The behaviour of lead and zinc is considered to reflect anthropogenic rather than natural variations in the lake conditions.

The geochemical patterns from the 2 lakes suggest that the lakes have been stable chemically during post *Ambrosia* time. The diatom inferred pH data, obtained from Lake CB_2 only, confirms this interpretation. The diatom inferred pH was 5.2 at a core depth of 1 to 1.5 cm, compared with a pH of 5.5 at a core depth of 4.0 to 4.5 cm. Because the water of the lakes was brown, indicating a significant amount of humic and fulvic acids in the lake waters, the lake waters might be expected to be buffered against the effects of acid precipitation.

These preliminary results show clearly to what extent the abundance pattern for chemical elements in post *Ambrosia* time vary in 2 lakes within the same catchment area. Although the lakes are relatively acid (at pH 5.1) the geochemical patterns suggest a stable chemical environment during the past few decades. This stability of pH conditions is confirmed by the diatom inferred pH data.

It is concluded that, except for the well known rise in zinc and lead which is common in all lake sediments of this type in the Wawa area, the abundance level of elements remains constant in a lake system buffered between 5.2 and 5.5 pH during post *Ambrosia* time. Further studies of 7 lakes, with different pH levels in waters and different diatom inferred pH histories, are currently underway.

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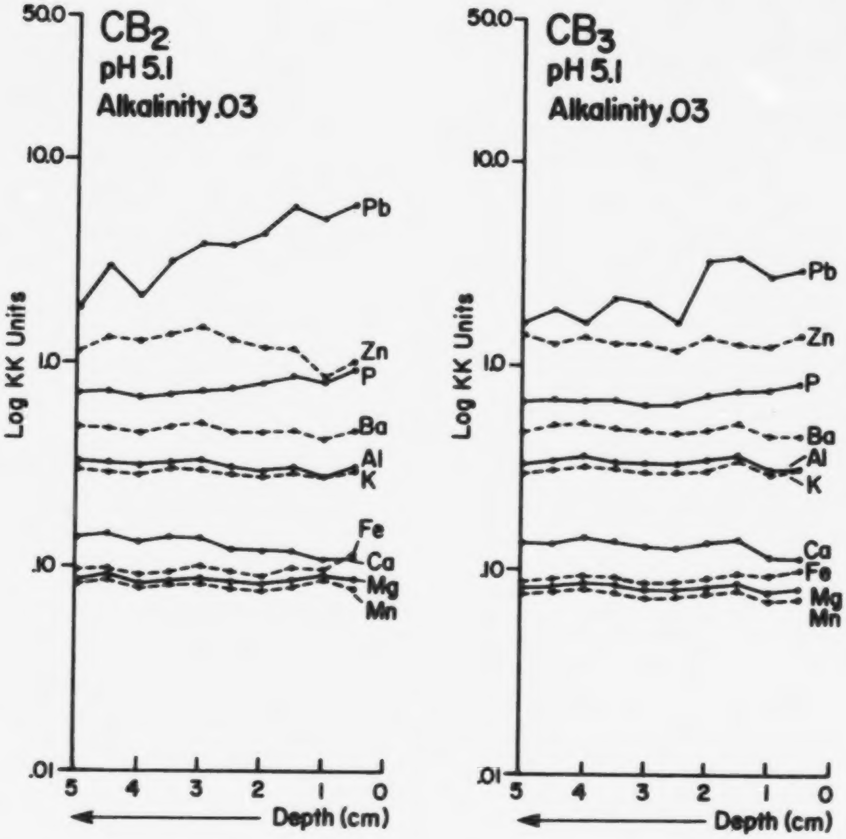


Figure 1. Abundance of elements in the post Ambrosia material from cores taken from 2 lakes in the CB catchment area, near Wawa.

No. 34 A Phased Approach to the Presentation of Regional Geochemical Survey Data From Southwest Ontario

John A.C. Fortescue[1]

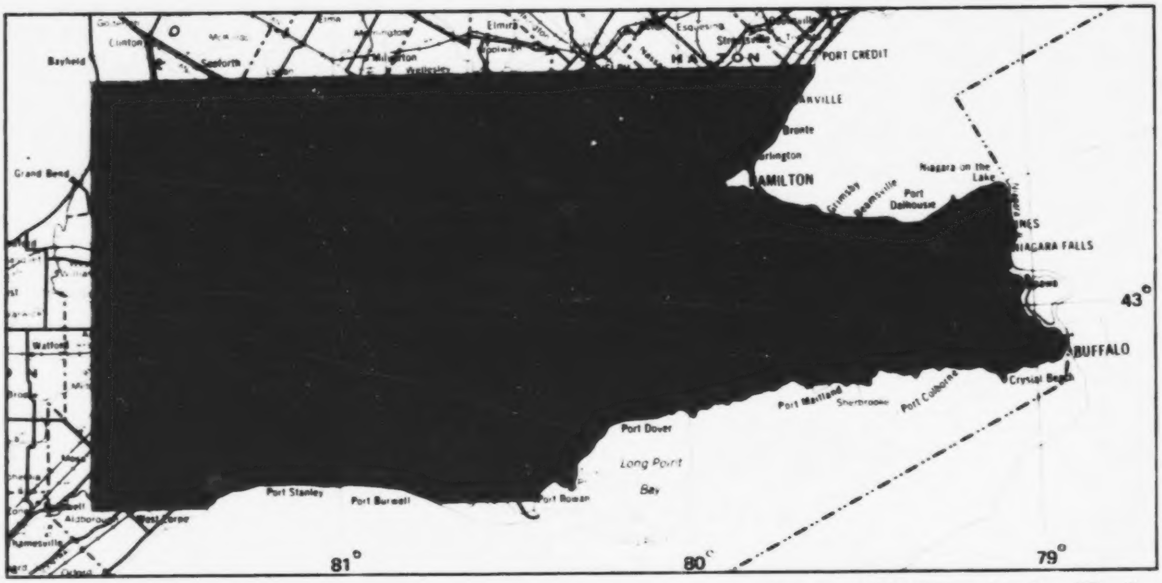
Introduction

In 1979, a plan was drawn up for a systematic regional geochemical survey of an area in Southwest Ontario designed to include mineral resource appraisal and environmental components. In the summer of 1981, the plan was implemented in an area of some 20 000 km^2 between the City of Niagara Falls and Lake Huron in Southwest Ontario. This resulted in the collection of stream sediment samples from over 4000 sites in the area (Thomson and Boni 1981). During the winter of 1981/1982, the stream sediment samples, including a series of 190 composite samples, were subjected to chemical analysis for each of 28 elements. In early 1983, work commenced on the preparation of an Open File Report designed to provide an overview of the Southwest Ontario geochemical data using a phased approach based on the chemical data from the 190 composites (Fortescue in press a, b). The purpose of this section is to provide an introduction to these 2 reports which are now in an advanced stage of preparation.

Objectives

The objectives of the project are:

1. to devise a relatively simple, phased approach to the preparation of regional geochemical maps designed for mineral resource appraisal and environmental purposes
2. to apply the phased approach experimentally to the data file for the Southwest Ontario regional geochemical survey


Clinton
Bayfield
Seaforth
Milverton
Wellesley
Elmira
Esquesing
Streetsville
HALTON
PORT CREDIT
OAKVILLE
Bronte
Burlington
HAMILTON
Grimsby
Beamsville
Port Dalhousie
Niagara on the Lake
NIAGARA FALLS
BUFFALO
Crystal Beach
Port Colborne
Sherbrooke
Port Maitland
Port Dover
Long Point
Bay
Port Rowan
Port Burwell
Port Stanley
West Lorne
Aldborough
Thamesville
Watford
Grand Bend
43°
81°
80°
79°

LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

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Methodology

Today almost all regional geochemical surveys are aimed at mineral resource appraisal or mineral exploration, although some attempts have been made to provide environmental interpretations of the geochemical patterns on such maps (Howarth 1983). In general, the interpretation of patterns on Canadian regional geochemical maps is based upon computerized statistical methods introduced into Canada in the 1960s by Nichol *et al.* (1966) and others. The interpretation of single and multielement regional geochemical data involve the study of patterns in chemical data obtained from all the samples collected during a regional geochemical survey in an attempt to relate them to simple or complex statistical models. One problem with this approach is that multielement analysis on the scale required for modern geochemical mapping is relatively costly and may exceed the cost of collection of the samples. A second problem is that the interpretation of the patterns is essentially mathematical without a conceptual component relating directly to the behaviour of particular chemical elements within the region surveyed.

The geochemical survey of Southwest Ontario was envisaged as a part of the geochemical map of Ontario. The preparation of a geochemical map of Ontario is a long-term goal because the Province is over 550 000 km^2 in area. This would require the collection of over 100 000 samples for the preparation of a regional geochemical map at the current sample density of 1 sample for every 5 km^2. Another problem is that the number of elements needed to be included in a regional geochemical activity currently exceeds 60, which requires 60 separate maps on a 1:250 000 map sheet for the detailed presentation of the single element chemical data for the samples.

The phased approach was devised to explore the possibility of:

1. reducing the cost of chemical analysis involved in the preparation of regional geochemical maps for mineral resource appraisal, exploration, environmental, and other purposes
2. introducing a scientific method for the interpretation of patterns on regional geochemical maps based on conceptual models which provide hypotheses which can be tested by statistical and field studies based on the regional data
3. designing an approach to regional geochemical mapping which can be used in any part of Ontario and be based on different sample media (i.e. lake sediments, stream sediments) as local conditions dictate
4. provide a method of presentation of geochemical data that is relatively simple to use for interpretative purposes by geochemists or other scientists not necessarily trained in geochemistry

Outline of the Phased Approach to Regional Geochemical Mapping

It was essential to so design the phased approach to preserve the objective of mineral resource appraisal (and exploration) as well as to provide geochemical information of environmental interest, bearing in mind the constraints mentioned above.

The phased approach was designed to attack all 4 constraints listed above simultaneously. The first decision was to preserve the sample density of approximately 1 sample per 5 km^2. To ensure this density, the mapped area was divided into 10 by 10 km squares which in turn were divided into quarters each 5 km on a side. The 5 sample site locations were always planned for each quarter, making a total of 20 sample site locations within each 10 km square. For purposes of identification and description, the 10 by 10 km squares were called "Micromodules" and the quarters "Micromodule Quarters". The geographical limits of micromodules were taken from the overprint of the Universal Transverse Mercator which is found on the 1:50 000 basemaps used for the sample collection process.

The use of micromodules allowed for a phased approach to the preparation of regional geochemical maps as follows:

> First Approximation Maps: Based on the chemical analysis of mixtures of equal weights of material from each of the 20 samples collected within a Micromodule (i.e. 1 sample for chemical analysis per 100 km^2 area).
>
> Second Approximation Maps: Based on the chemical analysis of mixtures of equal weights of material from each of the 5 samples collected within a Micromodule Quarter (i.e. 4 samples for chemical analysis per 100 km^2 area).
>
> Third Approximation Maps: Based on chemical analysis of material obtained from individual samples. This is the procedure currently used in regional geochemical mapping (i.e. 20 samples for chemical analysis per 100 km^2 area).

In this paper we are concerned with first approximation maps only. Information on the second and third approximations for the elements included in the Southwest Ontario survey is discussed in the 2 reports now in preparation (Fortescue in press a, b).

It is clear that the use of 20 sample micromodule composites reduces the number of data points on a geochemical map by a factor of 20, which reduces the cost of the chemical analysis substantially and allows the map fraction of the final maps to be much less than 1:250 000. In fact, a map plot of the 190 composites from the Southwest Ontario survey fits easily on a page the size of this report. Another advantage is that coded data for element 'X' in micromodule composites can be listed by a computer directly on a square plot. Then the preparation of first approximation geochemical maps becomes a simple matter of photocopying the data sheet for element 'X' with a transparent mask upon which the patterns of the bedrock lithology and Quaternary features are included (Fortescue in press a).

An important consideration in the preparation of first approximation geochemical maps is the reliability of the chemical data for the composite mixtures and the method for display of the data in order that geochemical patterns for one element within the region can be compared with patterns for other elements on a logical basis.

The first of these questions is solved by having strict quality control on the chemical analysis of the composite samples. This is done by inserting numerous replicates of standards at random within the analytical batch of composites. A simple criteria for inclusion of element 'X' within the regional geochemical map folio is if the coefficient of variation for the replicated standards is consistantly <5%. The 20 elements selected for inclusion in the Southwest Ontario first approximation geochemical maps were selected on this basis.

The second question is more complicated. In order to provide a geochemical datum as a basis for the comparison of the behaviour of elements in stream sediments, it was decided to transform all the "parts per million" (or "percent") chemical data into KK units by dividing each result from chemical analysis by the Clarke of the element concerned. The Clarke of an element is defined as an estimate for the weight percent of element 'X' in the earth's crust. This term was introduced by the Russian Geochemist, A.E. Fursman, in 1923 (Beus 1976) and is the geochemical equivalent of using sea level as a datum in topography. The main advantage of using the KK unit in regional geochemical mapping is that it makes all the resulting maps comparable to each other with respect to the geochemical abundance of the elements concerned. Like sea level, the Clarke is an estimate and varies with who made the estimate (Rickwood 1983). In the phased approach to regional geochemical mapping, KK units are used for the first and second approximations and parts per million at the third approximation (if this is desirable). The Clarke estimates used for the Southwest Ontario survey were taken from Ronov and Yaroshevski (1972) which are considered adequate for the 20 elements considered here.

After the performance of the analytical methods for element 'X' has been verified and the data transformed into KK units, the next problem is method of presentation of the data for each micromodule on a geochemical map. Just as topographic maps have a set contour interval, it is desirable for geochemical maps to have a set KK interval in order to produce comparable patterns from element to element. The interval chosen for the Southwest Ontario first approximation geochemical maps was 0.25 KK. Using this interval and an alphabetic code, it was practical to include all steps within the range 0 KK (= B) to 3.00 KK (= N). The letters above N could be used to express extremely high KK values.

As a result of these considerations, an atlas of 20 first approximation regional geochemical maps of the Southwest Ontario area was prepared (Fortescue in press b). In order to facilitate the recognition and interpretation of the single and multielement regional geochemical patterns, the procedure of gradient analysis, as described by Fortescue (1981), was applied to the atlas of Southwest Ontario geochemical maps. This was selected as an alternative to contouring because it has been found to facilitate the recognition and interpretation of regional geochemical patterns in data where there is considerable overlap between cell limits. Gradient analysis involves the plotting of a series of small map panels for each element. Using the micromodule procedure, the values for element 'X' which lie within a given KK unit cell (*see*above) are plotted as dots on a small map panel. The map panels for each element are then assembled into columns and the columns arranged in order of increasing KK values to produce a Scan Sheet (Fortescue 1970). In Figure 1, a Scan Sheet for 20 elements between 0 and 3.25 KK in the Southwest Ontario geochemical survey is presented.

Interpretation of Regional Geochemical Patterns

Clearly the patterns in Figure 1 are too small to be interpreted at this scale. However at a larger scale, a Scan Sheet of the type shown on Figure 1 provides a starting point for the recognition of patterns in the micromodule composite regional geochemical data. Because of the compositing process and the known reliability of the chemical methods for the determination of element 'X' in the composite samples, the patterns on resulting geochemical maps are assumed to be real.

In order to provide a first interpretation of the geochemical patterns on a Scan Sheet, 6 conceptual models for commonly recognized geochemical patterns (Fortescue 1980) have been drawn, each one of which is portrayed by a column of gradient analysis map panels. Comparisons are then made between the hypothetical ideal pattern models and the element patterns as they appear on the Scan Sheet. Once a pattern is recognized, it is used as the basis for an hypothesis for testing. Such tests may be made using quarter composite patterns, or individual data point results. For example, in the Southwest Ontario geochemical survey a "geochemical anomaly" was defined to include values >3 KK for element 'X'. Geochemical anomalies of this type were found for zinc in areas where sphalerite mineralization is known in bedrock and for nickel in the vicinity of a smelter.

Work on the phased approach to regional geochemical mapping is continuing under the current program for research and development.

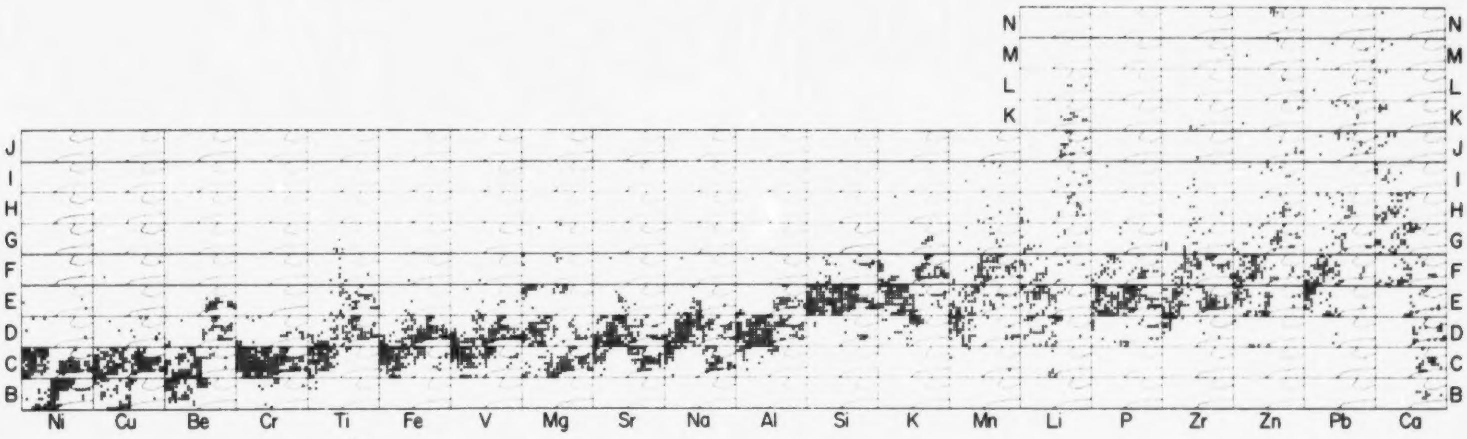

Figure 1. *Scan Sheet for Micromodule Composite geochemical data for 20 elements determined in samples from Southwest Ontario. Letter codes at the left and right of the figure indicate 0.25 KK data cell limits which increase from 0 to 0.25 KK (B) to 3.00 to 3.25 KK (N) for all elements. Each column of map panels includes data points for 190 micromodule composite samples. Individual map panels are small replicas of the Southwest Ontario area included in the regional geochemical survey. The interpretation of geochemical patterns on the Scan Sheet in relation to a series of conceptual models is described in Fortescue (in press b). This figure is designed to introduce readers to the general procedure of phased regional geochemical mapping only, and not to focus on details of the interpretative methodology.*

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No. 35 Further Studies of the Geochemistry and Mineralogy of Basal Tills and Related Materials from the Kirkland Lake Area, Districts of Timiskaming and Cochrane

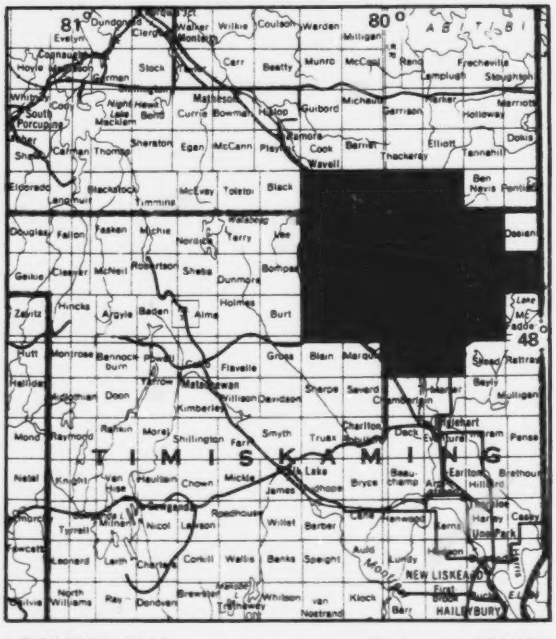
John A.C. Fortescue[1] and Jeanette Lourim[2]

Introduction

During 1983, work has continued on the samples of overburden material collected during the Kirkland Lake Initiatives Program (KLIP) which was a multi-year joint Federal-Provincial project that ends in 1983.

Data and information from the KLIP project geochemistry and descriptive mineralogy have been published in a series of reports (Averill and Thomson 1981; Routledge *et al.* 1981; Thomson and Lourim 1981; Lourim 1982a, 1982b; Thomson and Guindon 1979; Thomson and Wadge 1980, 1981). The latest report in this series, describing the 1981/1982 winter drilling program which was completed in Hearst, Catherine, McElroy, Gautier, Arnold, Clifford, and Bisley Townships, was released during the summer (Averill and Fortescue 1983).

Because of the multi-year nature of the KLIP program and the complexity of the data and information accumulated, it was decided in 1982 to prepare an Open File Report, including all information obtained from basal till and related materials during the project. Work on this report is now well advanced and the purpose of this report is to provide an update of progress since that described by Fortescue and Lourim (1982).



LOCATION MAP **Scale: 1:1 584 000 or 1 inch to 25 miles**

Objectives

The objectives of this project are:

1. to compile a single report in which all data and information from the 326 basal till sample sites is included in a form which may be used directly by explorationists interested in the Kirkland Lake area. This report contains geochemistry and descriptive mineralogy collected during the KLIP program.
2. to provide a state-of-the-art worked example for the interpretation of geochemical and decriptive mineralogy of tills collected from a part of the Kirkland Lake area within a corridor located in the direction of regional ice flow in the area.

Progress

Over 200 maps of the general type illustrated by Fortescue and Lourim (1982) have been prepared, together with detailed data listings for all the geochemical and mineralogical parameters which were measured from the 326 sample sites of basal till material from the KLIP area.

The worked example for the interpretation of the geochemical and mineralogical data was completed by a team including L.S. Jensen and C.L. Baker from the Ontario Geological Survey, Toronto, and Chris Gleeson, a

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[2] Geochemical Assistant, Geophysics/Geochemistry Section, Ontario Geological Survey, Toronto.

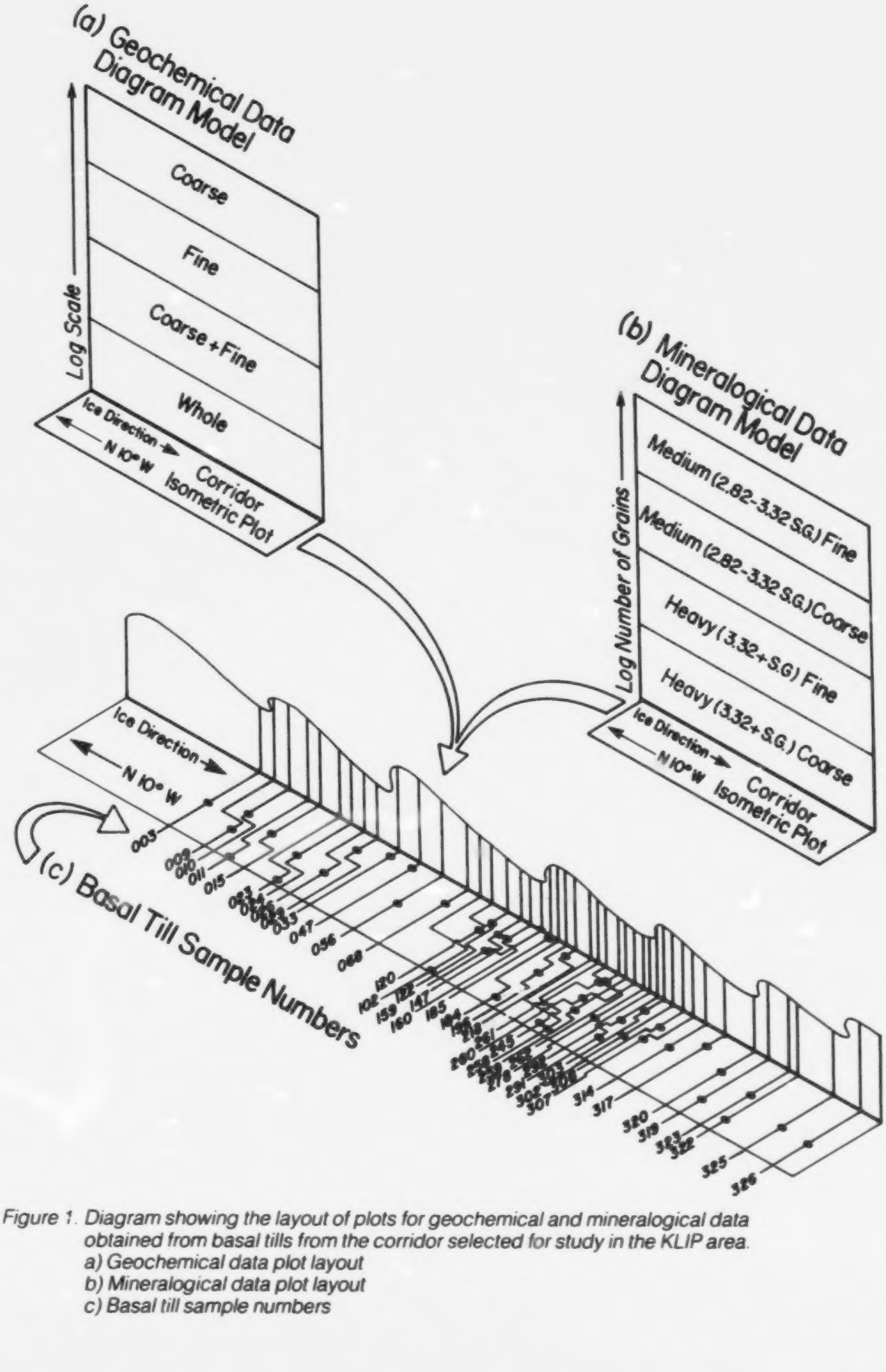
(a) Geochemical Data Diagram Model
Log Scale
Coarse
Fine
Coarse + Fine
Whole
Ice Direction
N 10° W
Corridor Isometric Plot
(b) Mineralogical Data Diagram Model
Log Number of Grains
Medium (2.82-3.32 S.G.) Fine
Medium (2.82-3.32 S.G.) Coarse
Heavy (3.32+ S.G.) Fine
Heavy (3.32+ S.G.) Coarse
Ice Direction
N 10° W
Corridor Isometric Plot
Ice Direction
N 10° W
(c) Basal Till Sample Numbers
003
009
010
011
015
047
056
068
120
102
122
159
147
160
185
314
317
320
319
323
322
325
326

Figure 1. Diagram showing the layout of plots for geochemical and mineralogical data obtained from basal tills from the corridor selected for study in the KLIP area.
a) Geochemical data plot layout
b) Mineralogical data plot layout
c) Basal till sample numbers

professional consultant in geochemistry. Because of the distribution of basal till sample sites within the corridor, and relationships between these locations and features of the bedrock and surficial geology of the area, it was not practical to plot the geochemical and mineralogical data sets obtained from the basal till material on a series of simple geological sections. Instead, an isometric format was used to display the location of each of the 44 sample points located along the corridor of interest. How this was done is illustrated in Figure 1, where the rectangular corridor is drawn as a quadrilateral with locations of basal till sample sites as elongated dots, the sample site numbers plotted at the left of the diagram, and either the geochemical or the mineralogical data plotted as graphs relating directly to the sample site locations. The method of plotting the geochemical information for a particular element in each of 4 size fractions of the tills is indicated in Figure 1a, and the method of plotting the data for the occurrence of a particular mineral species in each of 4 fractions of the till samples is indicated in Figure 1b. Using this system, data for 9 chemical elements and 9 indicator minerals in the 44 samples collected from the corridor area have been displayed. The geological interpretation of the assembled geochemical and mineralogical data provides an introduction to the interpretation of the data maps and files for 326 samples of tills which form the main body of the report. The Open File Report on the Basal Tills of the KLIP area is planned to be released during the next few months.

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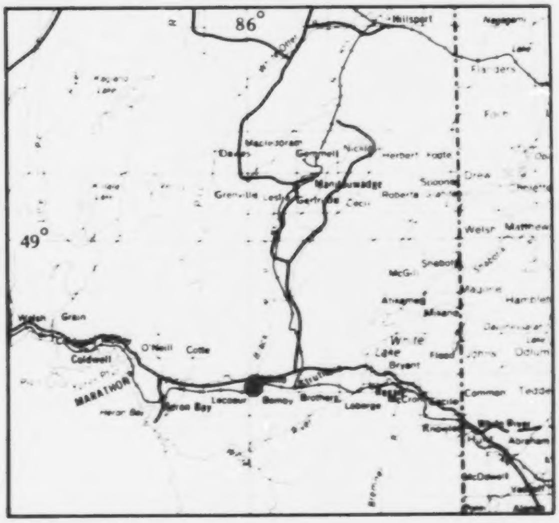
No. 36 A Small Scale Geochemistry/Quaternary Geology Study in the Hemlo Camp, District of Thunder Bay

John A.C. Fortescue[1] and R.S. Geddes[2]

Introduction

The Hemlo-Heron Bay area extending east from the north shore of Lake Superior includes a gold camp which is now being actively explored (Muir 1983). This exploration has sparked interest in the relative effectiveness of different geochemical techniques of mineral exploration in the area. To date, little detailed information is available on the scope of individual geochemical exploration techniques in the vicinity of covered mineralized zones in the Hemlo area. Meanwhile, plans are advanced for stripping and mining some of the deposits, which will destroy the landscape in these areas. For this reason a small scale surface geochemistry/Quaternary study has been completed in the area of one of the deposits about to be disturbed in order to place on record the relative effectiveness of different approaches to exploration geochemistry in the immediate vicinity of the deposit. General information on the problems and effectiveness of geochemical methods for exploration in Ontario may be obtained from the review by Fortescue (1983) which provides a background to this study.


86°
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Gertrude
Cecil
Roberta
Welsh
Matthew
McGill
Shebotik
Atikameg
Mikano
White Lake
Bryant
Flood
Johns
Odlum
Walsh
Grain
O'Neill
Cottle
Coldwell
MARATHON
Heron Bay
Lecour
Bomby
Brothers
Laberge
Common
Knowles
Abraham
McDowell

LOCATION MAP

Scale: 1:1 584 000
or 1 inch to 25 miles

Objectives

The objectives of this study are:

1. to complete geochemical investigations from the surface along 2 lines located partly above the mineralized zone, and partly up-ice and down-ice from the zone, in order to provide detailed information on the amount and distribution of elements in the humus, soil, and till material in the landscape
2. to complete the Quaternary and geochemical investigation of sections of overburden exposed in trenches located above, and beside the mineralized zone, in order to describe the geochemical effects of the mineralized zone on the glacial material and to interpret patterns in the geochemical data obtained from surface samples

Choice of Area

The Williams claim of Lac Minerals Limited, situated to the east of Moose Lake, was chosen for the study. After permission to inspect the property had been obtained from Lac Minerals Limited, a brief visit was made to the area to discover if it was suitable for a project of the type envisaged. Information obtained during the visit confirmed that the area of the mineralized zone was suitable for a combined surface geochemistry/Quaternary study, even though parts of the area had been disturbed by prospecting some years ago, and by recent pitting to expose the mineralized bedrock.

Progress to Date

Fieldwork involved in the study was completed by the writers in late August and early September 1983. The geochemical work involved laying out of 2 lines crossing the sub-outcrop of the mineralized zone (Figure 1). One line was located to pass between the 2 main exploration pits, from the crest of the low ridge to the north (i.e. up-ice from the deposit) to the alder swamp area, which lies immediately to the south of the mineralized zone and extends to the southern boundary of the claim near the highway. Samples of till near the bedrock were obtained from this line using a percussion drill, which, incidentally also gave an indication of the thickness of the surficial material along the line. Samples of humus were also taken along this line, although some stations were offset 30 m west to avoid disturbed ground. Samples of mineral soil horizons were taken where this was possible along the line as well. Chemical analysis of these samples is currently underway. A second line, parallel to the east boundary of the claim but located just to the west of the cut area, was sampled for humus and, where possible, mineral soil. These samples are also being currently subjected to chemical analysis.

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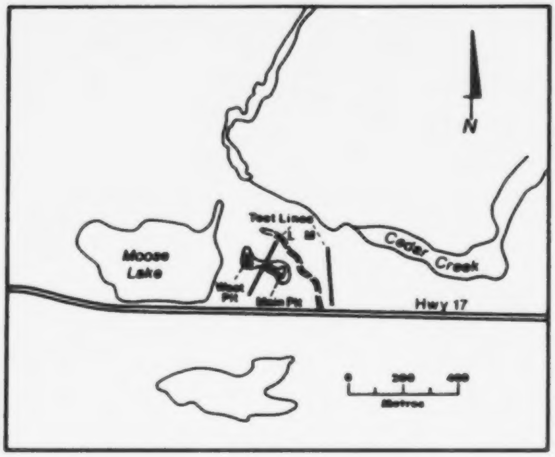

Figure 1. Sketch Map of the area around Moose Lake, Hemlo, showing locations of the pits exposing the orebody on the Williams option of Lac Minerals Limited, and the location of the 2 lines sampled during the Ontario Geological Survey geochemical study.

The Quaternary geological investigation involved a general study of glacial deposits of the area around the claim, including inspection of a large gravel pit situated 4 km to the north, just to the west of Highway 614. More specifically, the large pits in the area of the mineralized bedrock were examined in detail. Also examined were many sections of the glacial tills and related materials overlying the mineralized zone and adjacent areas of country rock. Initial field work indicates that the till sequence is complex and variable. For example, till appears to have been deposited over the ore zone predominantly by meltout processes, rather than by lodgement. This would provide an important control on the nature and extent of the glacial dispersion from the ore zone.

A series of 10 representative sections of the surficial material and soils were collected for later geochemical, textural, mineralogical, and geological study. This work will continue during the winter and results will be published in the near future.

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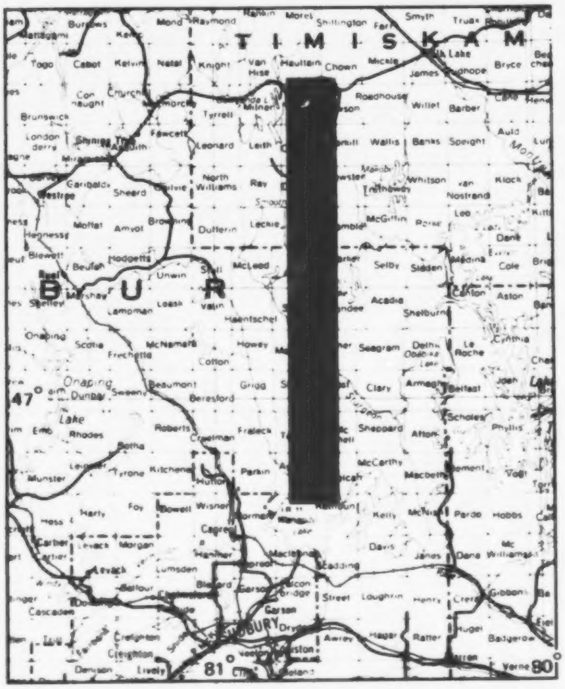
No. 37 A Small Scale Study of Acid Lakes in the Area North of Lake Wanapitei, District of Sudbury

John A.C. Fortescue[1]

Introduction

This study is one of a series designed to investigate the relationship between the methodology of regional geochemical mapping for mineral resource appraisal purposes and the problem of acid precipitation of lakes.

Previous studies in the Wawa area (Fortescue *et al.* 1981; Fortescue *et al.* in press) by an interdisciplinary team showed that for acid precipitation study, the determination of pH in lake waters during regional geochemical surveys was not sufficient. Other factors such as alkalinity, sulphate content, calcium content, and lake colour were also important clues to the pH history of lakes. During the research, Professor M. Dickman and his team from Brock University, St. Catharines, have developed a "diatom inferred paleo pH indicator method" for providing data on the pH history of lakes particularly in post *Ambrosia* time.



LOCATION MAP

Scale: 1:1 584 000
or 1 inch to 25 miles

The purpose of the 1983 research was to study the limnology and geochemistry of lakes with low pH in a new area in order to establish a wide validity for the diatom inferred pH indicator. Another purpose was to attempt to distinguish between naturally acid lakes and acid lakes in which the pH has been recently affected by atmospheric fallout.

A suite of 72 lakes, located to the northeast of Sudbury and to the north of Lake Wanapitei, was chosen for the 1983 study. Some of these lakes were known to be acid whilst others were known to have a neutral reaction thus providing a wide range in pH values for study.

Objectives

The objectives of this project are:

1. to study a series of 40 lakes located in a strip 10 km wide extending 100 km north from the shore of Lake Wanapitei in order to determine their pH and collect samples of their bottom sediment in order to provide diatom material for a calibration curve for the diatom inferred pH method and general geochemical information for environmental and resource appraisal purposes
2. to study the geochemistry and pH relationships of 32 lakes located in a 10 by 10 km area just to the north of Lake Wanapitei in order to provide detailed information for resource appraisal purposes and environmental purposes in an area where acid lakes are common
3. using the calibration curve derived from objective 1, to describe the pH history of 2 of the 72 lakes (one of which is naturally acid and the other which is believed to have changed pH during post *Ambrosia* time)

Methodology

The 100 km strip was divided into ten 10 by 10 km squares and each square again divided into four 5 km squares. One lake was selected for sampling in each of

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TABLE 1 **pH, SULPHATE, CALCIUM, AND MAGNESIUM OF WATERS TAKEN FROM 40 LAKES INCLUDED IN THE EXTENSIVE PART OF THE SUDBURY PROJECT (for explanation see text)**

AREA	DISTANCE FROM LAKE WANAPITEI (km)	LAKE 1	LAKE 2	LAKE 3	LAKE 4	MEAN
			pH			
Q	5	6.1	4.5	4.6	5.8	5.3
R	15	4.3	4.3	4.5	4.4	4.4
S	25	6.4	6.0	4.7	6.5	5.9
T	35	5.7	5.9	5.3	6.4	5.8
U	45	5.7	5.7	4.7	5.7	5.5
V	55	4.6	5.0	5.4	4.3	4.8
W	65	5.7	4.8	6.1	4.9	5.4
X	75	5.4	4.6	5.8	4.5	5.1
Y	85	7.6	8.3	6.4	4.6	6.7
Z	95	6.8	6.3	6.6	6.6	6.6
			Sulphate (ppm)			
Q	5	8	7	9	9	8
R	15	7	7	10	9	8
S	25	8	11	9	6	9
T	35	11	8	10	5	9
U	45	7	11	13	10	10
V	55	10	11	12	8	10
W	65	10	N.D.*	10	9	10
X	75	9	8	8	8	8
Y	85	7	10	6	5	7
Z	95	10	8	10	9	9
			Calcium			
Q	5	3.99	2.08	3.04	3.51	3.16
R	15	1.63	1.57	2.07	1.83	1.78
S	25	4.00	4.80	2.31	4.66	3.94
T	35	3.36	4.14	3.12	6.06	4.17
U	45	2.41	2.97	2.54	2.51	2.61
V	55	1.87	2.43	2.77	1.59	2.17
W	65	2.88	2.09	3.06	2.44	2.61
X	75	2.85	1.92	2.58	1.55	2.23
Y	85	15.02	17.26	3.16	1.34	9.20
Z	95	6.55	4.44	5.59	6.54	5.78
			Magnesium			
Q	5	0.75	0.71	0.73	1.12	0.83
R	15	0.53	0.56	0.66	0.60	0.59
S	25	1.06	0.98	0.74	1.24	1.01
T	35	0.88	0.98	0.78	1.80	1.11
U	45	0.75	0.90	0.79	0.85	0.82
V	55	0.60	0.83	0.90	0.46	0.70
W	65	0.93	0.72	1.03	0.74	0.86
X	75	0.89	0.58	0.90	0.49	0.72
Y	85	3.71	3.14	0.88	0.40	2.03
Z	95	1.21	1.29	1.55	1.71	1.44

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*Not Detected

the 5 km squares making a total of 40 lakes for study (*see* Location Map).

At each of the 40 lakes, Professor Dickman measured the pH of the water, water temperature, conductivity, and oxygen saturation simultaneously at 1 m intervals in the lakewater column using a special probe. An Ekman dredge was used to collect lake bottom sediment which was sub-sampled for diatom study and geochemical analysis immediately after collection. A sample of lakewater was collected to a depth of 5 m (in lakes where this procedure was practical) using a slowly filling water bottle.

The water sample was split at a field laboratory, one part being used for an alkalinity determination and the other for transport to the Geoscience Laboratories of the Ontario Geological Survey, Toronto, where pH and sulphate were determined and calcium, magnesium, and other elements were estimated using an ICP technique.

A series of 10 of the 40 lakes were later revisited and lake sediment cores obtained from them by a method described in Fortescue *et al.* (1981). Diatom inferred pH and geochemical studies are planned for 2 of these cores (one from a naturally acid lake and the other from a lake which may have recently changed pH).

Similar field work was carried out in the 10 by 10 km area except that lake sediment cores were collected from all lakes.

Preliminary Results

The data for pH, sulphate, calcium, and magnesium in the 40 samples of lakewater collected from the 10 by 100 km strip is listed in Table 1. In Table 1, the 10 km square areas are referred to by capital letters. For example, area "Q" includes the northern shore of Lake Wanapitei and its centre point is 5 km from the southern margin of the area. Area "R" is 10 km north of this and so on. Within each 10 km square, Lake (1) is in the northwestern corner, Lake (2) in the northeastern corner, Lake (3) in the southwestern corner, and Lake (4) is in the southeastern corner (Table 1).

In order to provide an example of the type of interpretation of the chemical data which may be attempted, let us consider some implications of the mean values for each of the 10 by 10 km squares as indicated at the right side of Table 1. Three hypotheses may be described from the data. Each requires confirmation using more data from the lakes and related catchment areas. The first hypothesis is that there is a geological feature in areas Y and Z which produces an increase in both calcium and magnesium in the waters and is associated with a significant shift in pH. This hypothesis is explained by the presence of glacial deposits in the area of Y and Z which are likely to have a relatively high content of calcium and magnesium carbonate.

A second hypothesis, similar to the first, can be used to explain the increase in calcium and magnesium in areas S and T. In this case, the increase in abundance of these elements is less and the associated change in pH of the lake waters is also less due to overburden. Clearly this hypothesis requires detailed and careful testing.

A third hypothesis is more subtle. It has to do with the sulphate level of waters in areas U, V, and W. In this case, the hypothesis is that the increased sulphate is derived from atmospheric fallout. The detection of a similar increase in the level of copper and nickel in the lake sediments from these lakes could provide independent confirmation of the hypothesis.

In summary, a study of 72 selected lakes to the north of Lake Wanapitei has been made to study relationships between the lakewater pH, the diatom inferred pH, and the geochemistry of the lakewaters and sediments. Preliminary information on the chemical patterns in 40 waters from 40 of the lakes allows for the description of 3 problems which are likely to be solved by future research now underway.

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GEOPHYSICS/GEOCHEMISTRY

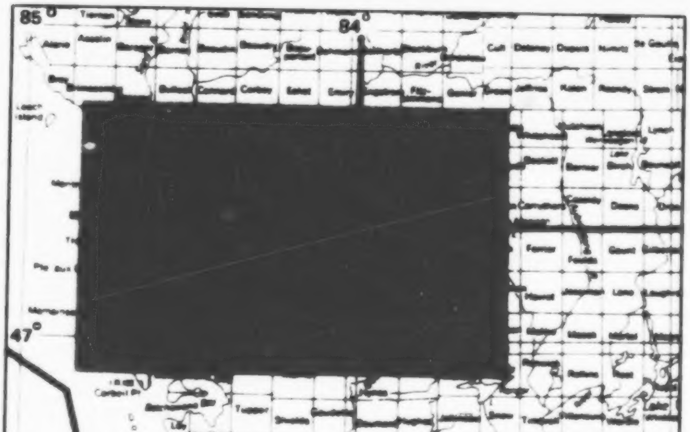
No. S38 A Small Scale Mineral Resource Appraisal and Environmental Geochemical Survey in the Batchawana Mountain Area, District of Algoma

John A.C. Fortescue[1] and Jeanette Lourim[2]

THIS PROJECT WAS FUNDED BY THE ONTARIO MINISTRY OF NORTHERN AFFAIRS THROUGH THE REGIONAL PRIORITY PROGRAM.

Introduction

The Batchawana Synoptic Project as described by Grunsky (1982) includes an area bounded by Latitudes 46°56'00''N to 47°30'00''N, and Longitudes 83°30'00''W to 84°50'00''W. It is an area where the Early Precambrian (Archean) metavolcanic-metasedimentary assemblage has been deformed, metamorphosed, faulted, and intruded by felsic intrusive rocks (Grunsky 1982). The area was covered in part by sedimentary rocks of the Huronian Supergroup. Keweenawan volcanics overlie the Early Precambrian (Archean) supracrustal and plutonic rocks at the western edge of the area. Grunsky (1982) also noted that the area has had 2 significant copper producers, the Tribag and the Coppercorp Mines, both in post-Keweenawan rocks. Other known mineral deposits in the area include the Goulais River Iron Range at Cowie Lake and small base-metal showings in the Grey Owl Lake area. A quartz vein at the contact of the Grey Owl Lake stock contains 0.54 ounce per ton silver and trace gold (Grunsky 1981). In summary, the Batchawana Mountain area includes a number of environments that are potentially good hosts for economic mineral deposits, although the area has received relatively little exploration attention in the past. The small scale study described here is de-



LOCATION MAP **Scale: 1:1 584 000 or 1 inch to 25 miles**

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[2] Geochemical Assistant, Geophysics/Geochemistry Section, Ontario Geological Survey, Toronto

signed to focus attention on the mineral potential of the area and provide information required for the planning of a large scale geochemical survey in the region at some later date.

Objectives

The objectives of this study are:

1. to complete a regional geochemical survey of an area of some 1000 km^2 located in the vicinity of known mineral deposits and showings in the Batchawana Synoptic Project area, in order to focus attention on the mineral potential for exploration in the area based on data from chemical analysis of lake and stream sediment material
2. to include an environmental component in the geochemical survey which will provide useful information to environmental scientists who study the problem of acid precipitation effects in the area, particularly those engaged in the Turkey Lakes Watershed Study which is included in the area of the geochemical survey

Methodology and Progress Report

The geochemical survey involves the collection of lake sediment samples at a uniform density within specified areas within the Batchawana Synoptic Project Limits. The areas were specially selected for their possible mineral potential by E.C. Grunsky (Geologist, Precambrian Geology Section, Ontario Geological Survey, Toronto) and G.A. Bennett (Resident Geologist, Ontario Ministry of Natural Resources, Sault Ste. Marie).

At the time of writing, plans for the field work are far advanced and the collection of samples is due to begin in late September, using a helicopter to gain access to remote lakes. Unlike previous geochemical surveys in the area, the 1983 study will include the determination of a wide range of major and minor elements in the lake and stream sediments, including gold and silver. Lake waters will also be sampled and pH, alkalinity, sulphate content, and cations (i.e. Ca and Mg) will be determined. The project is designed to be completed by April, 1984.

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Mineral Deposits Programs

Summary of Activities, Mineral Deposits Section, 1983

A.C. Colvine[1]

The shift in program philosophy and attendant project style, evident in the summary for 1982, has been substantially developed during 1983; the following reports now constitute components of a multifaceted program to systematically investigate and document the geology of mineral deposits in Ontario. The principal intended client group for this work is the minerals exploration industry; the database documentation is supplemented by specific investigations which are direct applications of "research" techniques to exploration. In addition, the Mineral Deposits Section maintains a continuing role as a service group in government planning. The co-ordinated program outlined below has partly arisen from initiatives to ensure better staff effectiveness and to increase involvement of geologists outside of the Section. The vast increase in projects reported has been brought about by development of small entities which build towards the overall program. This has been achieved through limited selective direct funding and cooperative arrangements, rather than by an increase in staffing or funding.

The staffing level of the Mineral Deposits Section (8 people, including 6 staff geologists) is inadequate to cover the broad mandate assigned to it. It is therefore necessary for each geologist to become active in specific thematic projects, so that the work of other geologists can be successfully integrated and applied. These thematic projects are the basic project components of the Section, comparable to, for example, a Precambrian mapping project, and subcomponents in each are merely a contribution to that basic project. The 7 principal means of drawing upon additional expertise are as follows:

1. Additional funding has been granted to the Mineral Deposits Section to conduct community-based and commodity-oriented projects as an aid to economic stimulation. While this is a worthwhile goal, which is being achieved, the effect of the work can be increased substantially where the contract project geologists both draw upon and contribute to the base program work of the Section. To clarify this relationship, "Special Projects" have been included in the relevant sections of the report, rather than listed at the end where their full impact would be lost; the funding source for each (Ontario Ministry of Northern Affairs, Federal Department of Regional Economic Expansion (DREE), and Ontario Ministry of Natural Resources) is clearly identified and acknowledged.
2. Regional geological staff of the Ontario Ministry of Natural Resources are a major component of the Ontario Government's commitment to the mineral resource sector. The Mineral Deposits Section has made considerable effort to draw upon this resource through development of cooperative project work. An attempt has been made to cover all of these activities in the following summaries, and several individual projects are reported separately.
3. Universities host a major source of expertise, largely untapped in the applied field. Cooperative projects have been developed with individuals at many universities in Ontario to conduct specific studies which are contributing to the main program thrust.
4. Mission-oriented university research projects are funded by the Ontario Government through the Ontario Geoscience Research Fund. Once funds have been awarded by the Grants Committee, specific projects directly relating to the Ontario Geological Survey program can be carried out in a mutually beneficial manner in which cooperation is fostered. Field work reports from some of these projects are included here to make results available as quickly as possible and to show them in the context of other studies.

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[1] Section Chief, Mineral Deposits Section, Ontario Geological Survey, Toronto

5. Increased cooperation is being developed with staff of the Federal Government to maximize the benefits of public expenditure.
6. Universities possess specialized equipment well beyond the resources of the Ontario Geological Survey. Major advances in research and technology are being made at universities, but more effort is needed in the practical application of this work. The Mineral Deposits Section is not a pure research group (for example, many people in the pure research field do not consider field mapping as a research activity), but it has a major imperative to bridge the present gap in research and investigate the practical applications of specialized research. To this end, cooperative arrangements have been initiated with research specialists at several universities to attempt direct practical application of their techniques; expertise from both sides is essential if this venture is to prove successful.
7. Lastly are the vast resources of knowledge possessed by industry geologists. Cooperative work has led to submissions for publication by many individuals.

Rather than minimizing the work of the Mineral Deposits Section, these cooperative arrangements add substantially to it, as the greater our knowledge becomes, the more aware we become of the major deficiencies in our knowledge. The field of mineral deposits geology is vast, especially within Ontario where mineral resources are a leading contributor to the wealth of the Province. These constraints require that the program philosophy have 3 components:

1. to maintain general expertise in all aspects of the mineral deposits geology of Ontario
2. to focus resources in a limited number of program areas so as to satisfy, quickly, a current demand for improved information or to stimulate interest
3. to conduct limited new studies in specific areas to investigate economic potential and the requirements for further work

The principal program focus of the Mineral Deposits Section over the past 2 years, in response to obvious demand, has been to investigate Archean lode gold; approximately half of the resources of the Section have been applied to this program. A second program thrust, involving 2 staff geologists at present, has recently been initiated to investigate new economic opportunities in industrial minerals; this program will gradually be built up and run in parallel with the gold program.

In addition, specific project work is being carried out in several other areas of mineral deposits, although resources do not permit work to a level which would result in comprehensive advances. If the need is identified, greater resources will be redirected to these areas. M.E. Cherry has initiated a study of mineralization in gneissic terrains and will further develop this work in cooperation with the Precambrian Section and regional staff. Leo Owsiacki is mapping and investigating the potential of Archean supracrustal sequences in the Cobalt and Temagami areas. K.H. Poulsen is completing a comprehensive metallogenetic study of the Fort Frances-Mine Centre area. Soussan Marmont has prepared a report on the mineralization of the Terrace Bay area and is completing a report on mineralization associated with Archean granitoid stocks (porphyries?). The Huronian program continues to provide specific studies on parts of individual formations, but resources do not permit the comprehensive, integrated studies which are needed. In the Grenville Province, projects are being conducted by the Mineral Deposits Section and regional staff, largely through supplementary funding; much of this work is contributing to the industrial minerals program.

The structure of the program, overall, is further outlined in the following reports. Each section contains an introduction to the program components by the co-ordinator to clarify the interrelationships of projects and to avoid duplication of rationale in each report. Component summaries also list other relevant work in progress and recent or forthcoming publications.

Lastly, the Mineral Deposits Section has made a major effort in communication and technology transfer. To exist, a government agency must serve a useful role in society; the intended client group for our work will be the judge of its usefulness. Believing this, we have made great efforts to make the results of our work as widely available as possible. More than 100 public presentations have been made throughout Ontario and selected locations in Canada in the past year. Efforts have been made to publish as rapidly as possible, even where work is at an interim stage; an example of this is the release of "The Geology of Gold in Ontario" (Ontario Geological Survey, Miscellaneous Paper 110) in April 1983, documenting the state of our work to January 1983. Articles have been prepared for outside publication. A discussion conference was arranged by the Section involving more than 40 exploration staff, essentially a "trade show" on the state of geological knowledge of gold deposits. Our efforts are clearly proving fruitful, as evidenced by greatly increased communication with exploration geologists. We are confident that this will lead to the ultimate objective of the program; to contribute to the discovery of new mineral wealth in Ontario.

ARCHEAN GOLD PROGRAM

Introduction by A.C. Colvine[1]

This program constitutes a systematic study of the geological associations of gold mineralization in the Superior Province of Ontario. The objectives of the program are to document the immediate geological setting of as many individual gold deposits as feasible and to study these deposits in the context of their regional geological setting. No practical geologist can be naive enough to think that this work will make exploration for gold easy, but conversely, no practical geologist would ignore the information gained from thorough study of known deposits.

Virtually all of the work reported herein constitutes field-based mapping studies. There are numerous documented examples which demonstrate conclusively that the understanding of an individual deposit can be increased very substantially where adequate field studies are conducted to document geological relationships as fully as possible. Any attempt to employ the range of sophisticated laboratory techniques presently in the geologist's arsenal based on generalities and misconceptions about geological relationships is, at best, of marginal use, and at worst, detrimental to the advancement of geological science. Follow-up laboratory studies are being, and will be further, applied as a component of this program, but only to answer specific questions in well researched problems; increased cooperation with university staff possessing specific research skills will be the principal means of conducting this component of the program.

In the present era of geological research, discussion and controversy commonly centre around interpretation and alternative genetic models. This has led to the unfortunate situation in which extrapolations of inadequate data are being made without significant discussion of the validity of these data. The work presented herein does contain interpretation; in each instance, however, the emphasis is placed on the description of the database and interpretations are clearly separated and identified. The geological descriptions are of a quality to be of lasting value, long after genetic biases have changed.

The word "structure" has a prominent place in many of the reports and the reader may think that an inordinate bias exists in this component of our work. Three reasons can be cited for this emphasis:

1. Over the last 20 years, basic mapping emphasis has been placed on lithological mapping, leading to volcanological and stratigraphic interpretation, which is the essential database in the search for volcanogenic massive sulphide mineralization; only minor emphasis has been placed on structural and related tectonic study.
2. There are numerous documentations of the structural control of localization of gold on the deposit scale. Similarly, deposit concentrations occur within regional zones of structural complexity.
3. Ontario Ministry of Natural Resources geologists, working independently, have documented previously unrecorded geological features, including structural features, associated with many gold deposits. While the relationship of gold to these features is uncertain, the features must be recorded.

Structure is as important a component of geology as, for example, lithology, and yet for many geologists lithological mapping is perceived as synonomous with geological mapping. The writer has commonly heard the opinion, although never from mine geologists, that structure is of minor importance in gold deposits where virtually no information exists on the structural setting; if only lithology is mapped, then only 1 component of geology is being used to aid our understanding of gold deposits.

Present Program

Planning of a geological program must be continually revised on the basis of experience gained, even if the topic was well researched initially. Based on conventional wisdom, the program has focused on specific associations deemed important (Colvine 1983); the relationships with felsic intrusions (Cherry 1983; Marmont 1983), iron formations (Macdonald 1983), and alteration (Andrews and Wallace 1983) were selected for study. Experience has shown that individual components could not be examined in isolation and the trend of work has rapidly shifted to the comprehensive study of the complete geological setting.

Other studies have reinforced this program change. The compilation of gold deposits in the Abitibi Belt (Hodgson 1983) demonstrated that many preconceived hypotheses about critical associations were not statistically valid; the report and database from this study will be released shortly (Hodgson in press), and the user-accessible computer file will be available thereafter. In a comprehensive study of the geology and mineralization of a specific area, the Fort Frances-Mine Centre area, K.H. Poulsen (1983) demonstrated that gold mineralization was superimposed on a variety of host lithologies. The structural localization of individual deposits was documented and shown to be related to a regional deformation zone, highlighting the need to consider regional components often overlooked in isolated deposit studies. The report from this study will be released shortly (Poulsen in press).

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While the approach to the program still consists of detailed studies of specific deposits and associations, the regional setting is an increasingly important component. Program components in individual "greenstone belts" are therefore grouped together (Figure 1). In addition, several other components have been added to the program.

The work in the Abitibi Belt is being co-ordinated by M.E. Cherry. This belt, the largest and most productive in the Precambrian Shield, still lacks complete detailed mapping coverage, and aspects of its stratigraphy and structure remain the subject of controversy. In this environment, and within the constraints of this program, a comprehensive coverage of gold mineralization is not possible. The reported studies are an attempt to document specific deposits and associations which will be added to the database, and in time lead to a more complete description of this area.

Initial work in the Geraldton area by the program co-ordinator (Macdonald 1983) demonstrated that gold localization was along plunging 'Z'-shaped fold structures. The presupposed genetic link with iron formation was questioned; no iron formation is present in 2 areas of major production at Geraldton, and no evidence of anomalous background gold concentration in iron formation was found. This work permitted the definition of the projects reported herein, both on the detailed and regional scale; preliminary work has also been started in the Beardmore area. In addition, a reconnaissance of previously unmapped areas has uncovered zones of alteration, deformation, and veining of similar style to that documented in the areas of known mineralization.

The work in the Red Lake area, being co-ordinated by A.J. Andrews and M.E. Durocher, holds considerable promise for a comprehensive evaluation of gold occurrences in a single belt. The work in the Madsen area, in particular, has greatly clarified relationships; outcrops were cleared which demonstrated that the host unit to the gold, previously named the Austin Tuff, is intensely sheared pillowed mafic volcanic rocks rather than a conformable mafic tuff; in addition, mineralogical and lithogeochemical alteration halos have been defined which may have a direct application in exploration geochemistry in other areas. On the basis of this experience, M.E.Durocher is examining the western part of the belt and has delineated a major deformation zone with possible alteration halos. A similar study of the northeastern part of the belt by A.J. Andrews has included specific structural studies which may help clarify relationships in this complex area.

In virtually all studies, field relationships clearly define the relative sequence of events; absolute dating would help determine the relative importance of the numerous documented geological parameters. Soussan Marmont is coordinating the age-dating program of the Mineral Deposits Section, to consolidate the work and accelerate the program. Sampling was carried out in the Red Lake and Abitibi Belts for dating by the U-Pb Zircon technique, at the Jack Satterly Geochronology Laboratory, Royal Ontario Museum, Toronto, in cooperation with F. Corfu and T. Krogh. Preliminary investigation was also made of the application of direct dating of ore gangue minerals by the ^{40}Ar/^{39}Ar technique developed by D. York at the University of Toronto.

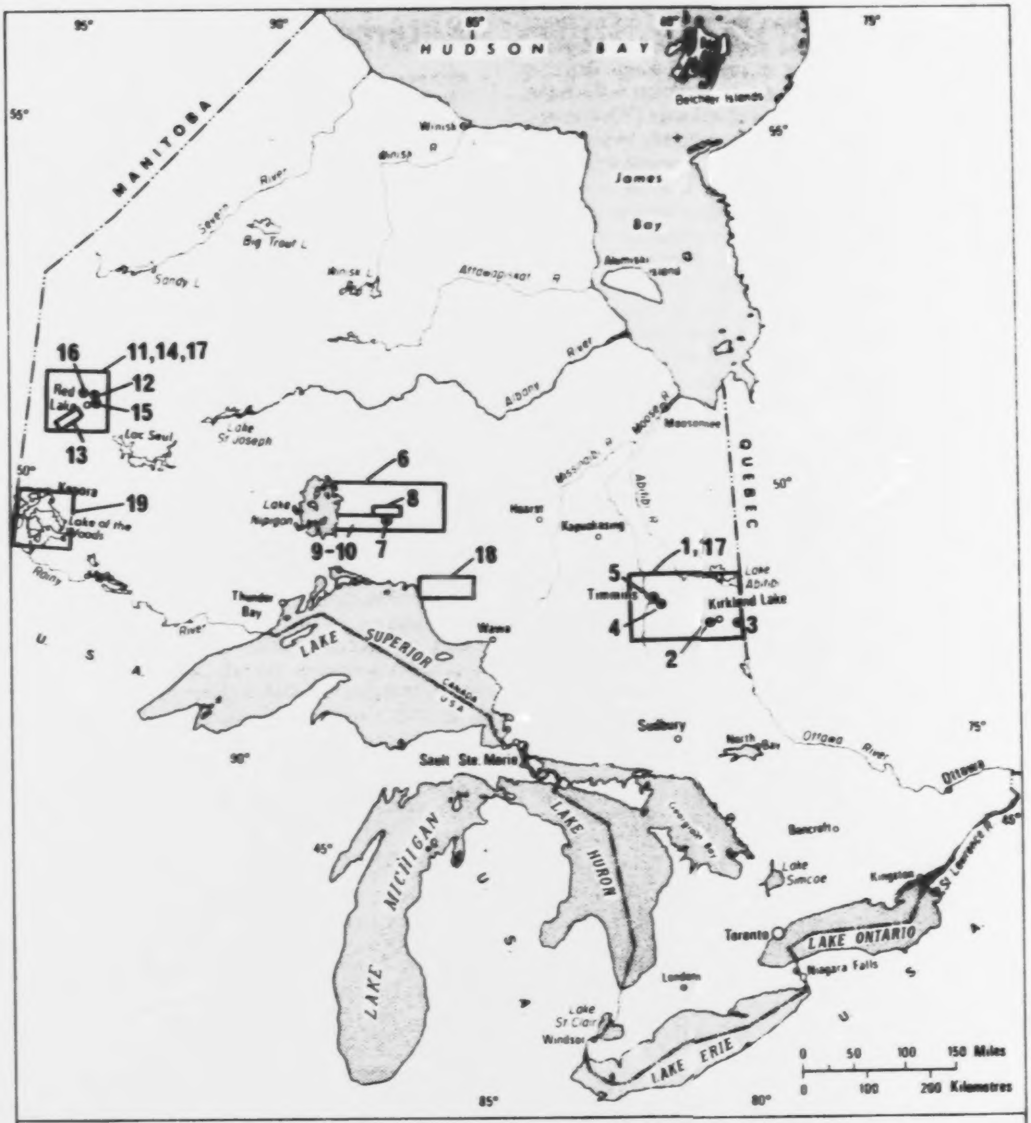
The Hemlo area has received major exploration attention during this year. G.C. Patterson, Resident Geologist, Ontario Ministry of Natural Resources, Thunder Bay, has a cooperative project with the Mineral Deposits Section to study aspects of mineralization in this area. The speed with which the "Hemlo-type" has been named, without significant documentation of its geological associations, is disconcerting. While time constraints have not permitted adequate new work, some of the unreported geological complexities of this area are described. An attempt is also made to document the proliferation of university research projects.

In the Lake of the Woods area, J.C. Davies has initiated a 2-year project to document occurrences of gold mineralization. Based on his extensive experience in this area, it should be possible to evaluate the overall distribution of mineralization in the context of its stratigraphic and structural setting.

The Cameron-Rowan Lakes area is presently the focus of considerable exploration activity; the area is presently under study by C.E. Blackburn, Resident Geologist, Ontario Ministry of Natural Resources, Kenora. At the Cameron Lake Deposit, mineralization is hosted by a zone of sheared pillowed mafic volcanic rocks, which in cursory examination might be mistaken for interflow sedimentary rocks; this feature may have a direct analogy to the Austin Tuff in the Madsen area of Red Lake, and has some similarities to the described features in the Bankfield-Tombill fault zone in the Geraldton area. Definition of the structural setting is therefore of paramount importance as a guide to further exploration targets in this area.

Summary

In evaluating exploration criteria it is essential to draw on detailed studies in many different areas to determine consistencies and differences; by this process, the essential characteristics may be separated from those which are not important components of the mineralizing system. It was by this method that the important associations of volcanogenic massive sulphide deposits were determined, providing useful guidelines for further exploration; in this process the importance of such features as "rhyolite-andesite" contacts, drawn from the Noranda Camp, were misinterpreted and misapplied at an early stage.


HUDSON BAY
Belcher Islands
James Bay
MANITOBA
QUEBEC
Winisk
Winisk R
Severn River
Big Trout L
Sandy L
Attawapiskat R
Albany River
Lake St Joseph
Lac Seul
Red Lake
Kenora
Lake of the Woods
Rainy River
Lake Nipigon
Thunder Bay
Hearst
Kapuskasing
Moosonee
Moose R
Missinaibi R
Abitibi R
Timmins
Lake Abitibi
Kirkland Lake
Wawa
LAKE SUPERIOR
Canada
USA
Sault Ste. Marie
Sudbury
North Bay
Ottawa River
Ottawa
Bancroft
Lake Simcoe
Kingston
St Lawrence R
Toronto
LAKE ONTARIO
Niagara Falls
London
Lake St Clair
Windsor
LAKE ERIE
LAKE HURON
Georgian Bay
LAKE MICHIGAN
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1. Cherry
2. Cherry, Watson, and Nemcsok
3. Hamilton
4. Piroshco
5. Wood

6. Mason and Macdonald
7. Macdonald
8. Lavigne
9. Kehlenbeck
10. Fralick and Barrett

11. Andrews and Durocher
12. Andrews
13. Durocher and Hugon
14. Durocher and Burchell
15. Sanborn
16. Berger and Summers

17. Marmont

18. Patterson

19. Davies

Figure 1. The location of "Archean Gold" projects.

In an evaluation of gold deposits, the lack of consistency in lithological associations and apparent volcanological-sedimentological environment is most striking. Beyond the common, but not ubiquitous, association with mafic volcanic rocks, in some instances of a lower tholeiitic-komatiitic sequence, gold occurs with virtually every lithological type. If we are to evoke a primary depositional environment for gold concentration, it is difficult to define what these environments are, in comparison to the well defined environment of deposition for massive sulphide minerals. Also, no candidate protore concentrations have been identified in studies of this program.

There are, however, clear consistencies between some features of most gold deposits studied in this program and deposits described in the literature. The present siting of gold is one of the latest geological events in each area, and its location is controlled, at least in part, by structural parameters. In addition, gold deposits are located in linear zones of much greater structural complexity than prevalent in surrounding parts of "greenstone belts".

As stressed previously (Colvine 1983), the recognition of critical features is important at this stage, regardless of their genetic interpretation. The very common structural component to gold mineralization cannot be ignored, at either a property or regional scale. This is valid regardless of genetic theories, whether it be an essential component of "remobilization", or a more fundamental component of the mineralizing system.

The emphasis on comprehensive documentation of all geological features associated with gold mineralization will continue, within the constraints of time and the abilities of the geologists involved. Many of the field relationships reported are critical and cannot be adequately demonstrated in talks and photographs. An attempt will therefore be made next summer to establish a series of field study sessions to examine these with interested geologists in order to establish whether or not we indeed have an adequate and mutually acceptable database before progressing to the next stages of this program.

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Gold Studies in the Abitibi Greenstone Belt

Introduction by M.E. Cherry[1]

Fundamental geological relationships in the Abitibi greenstone belt that are pertinent to understanding Archean lode gold deposits remain poorly described and understood, and controversial in their significance and interpretation. This is despite the lengthy histories of geological mapping, mineral exploration, and gold mining in the belt. The importance of gold mining in the Abitibi is reflected in continuing production from the Hollinger, McIntyre, Pamour, Ross, Owl Creek, Macassa, and Kerr Addison Mines; the re-opening of the Lake Shore Mine and the planned opening of the Hoyle Pond, Carshaw, Wright-Hargreaves, and McBean Mines; and continuing evaluation of known deposits such as the Orofino, Davidson-Tisdale, and Quebec Sturgeon. The large size of the Abitibi belt, and the concentration of known gold deposits in 2 widely separated linear camps, i.e. Porcupine and Kirkland-Larder Lakes, contrast with the Beardmore-Geraldton and Red Lake gold camps, in which deposits are closer together in substantially smaller "greenstone" volcanic-sedimentary rock packages. As a consequence of these factors, the studies of gold deposits in the Abitibi greenstone belt by the Mineral Deposits Section are less co-ordinated than those of equivalent programs in the Beardmore-Geraldton (Mason and Macdonald, this volume) and Red Lake (Andrews and Durocher, this volume) areas.

Projects in the Abitibi belt in 1983 focused on careful and thorough documentation of problematic relationships of gold deposits in Kirkland Lake, Virginiatown, and Timmins (Figure 1), ranging from an investigation of a particular mineral association in a single orebody to regional stratigraphic and structural analyses. Many of the intriguing and problematical relationships of these gold deposits were documented by Hodgson (1983a, 1983b).

Two projects were begun in the Macassa Mine at Kirkland Lake. This mine, despite its longevity and continuing importance to Canada's gold mining industry, has received little attention, as evidenced by the fact that the last published description of its geology appeared in 1964. Watson and Nemcsok (Cherry, Watson, and Nemcsok, this volume) have undertaken a new description of the geology of the mine, which will include the extensive development since 1964 in the western end of the mine. The compilation, which is to comprise plans, sections, photographs, and a general discussion, is an important addition to knowledge of the Kirkland Lake gold deposits. The author (Cherry, Watson, and Nemcsok, this volume) continued his study of the association of lode gold deposits with felsic intrusions (Cherry 1983) by examining and sampling the syenites in the Macassa Mine. This study will document the petrogenesis of the syenites and the alteration, which is associated with mineralization, that has affected them. Similar studies are planned for the felsic porphyries in the Timmins camp.

J.V. Hamilton began detailed geological mapping in McGarry Township near the Kerr Addison Mine at Virginiatown. The emphasis of this research (Hamilton, this volume), which is part of an M.Sc. program at Queen's University, Kingston, under the supervision of C.J. Hodgson, is to define the major and minor structures in the area, and to relate these structures to igneous events, alteration effects and ultimately, to gold mineralization.

Two M.Sc. programs were begun in the Timmins area with support from the Mineral Deposits Section. P.C. Wood (this volume) under the supervision of E.T.C. Spooner of the University of Toronto, is investigating the significance of scheelite in the Hollinger-McIntyre orebody by documenting its distribution and carrying out extensive petrological and analytical studies. D.W. Piroshco (this volume), working with Hodgson at Queen's University, mapped the surface geology of the Coniaurum Mine at 1:2400 scale and will complete a structural analysis of this geology to interpret its deformation history and the relationship of this history to gold mineralization.

Complementary to these studies of deposit-specific problems is a program of radiometric age-dating in the Abitibi belt begun in 1983 and described elsewhere in this volume by Soussan Marmont. This program addresses the more general problems of stratigraphic correlation across the Abitibi belt and the timing of felsic magmatism during development of the greenstone belt, both are of paramount importance in understanding how the gold deposits were formed.

Other investigations related to gold deposits were carried out in the Abitibi belt in 1983 by both government and university geologists. N.F. Trowell of the Precambrian Geology Section of the Ontario Geological Survey continued synoptic mapping in the Black River-Matheson area, and L.S. Jensen, also of the Precambrian Geology Section, continued geological mapping at 1:50 000 scale in Matachewan-Kirkland Lake area. J.H. Crocket and co-workers from McMaster University, Hamilton, continued an extensive study of the geology and chemistry of banded iron formations near Kirkland Lake and Temagami. This work, which is funded by an Ontario Geoscience Research Fund (OGRF) grant, is to evaluate Archean banded iron formation as an exploration guide to precious and base-metal mineralization. In reference to gold deposits, the research will evaluate whether the known spatial association of gold deposits with iron formation results from a primary metal concentration in the iron formation, a post-lithification concentration, or is accidental.

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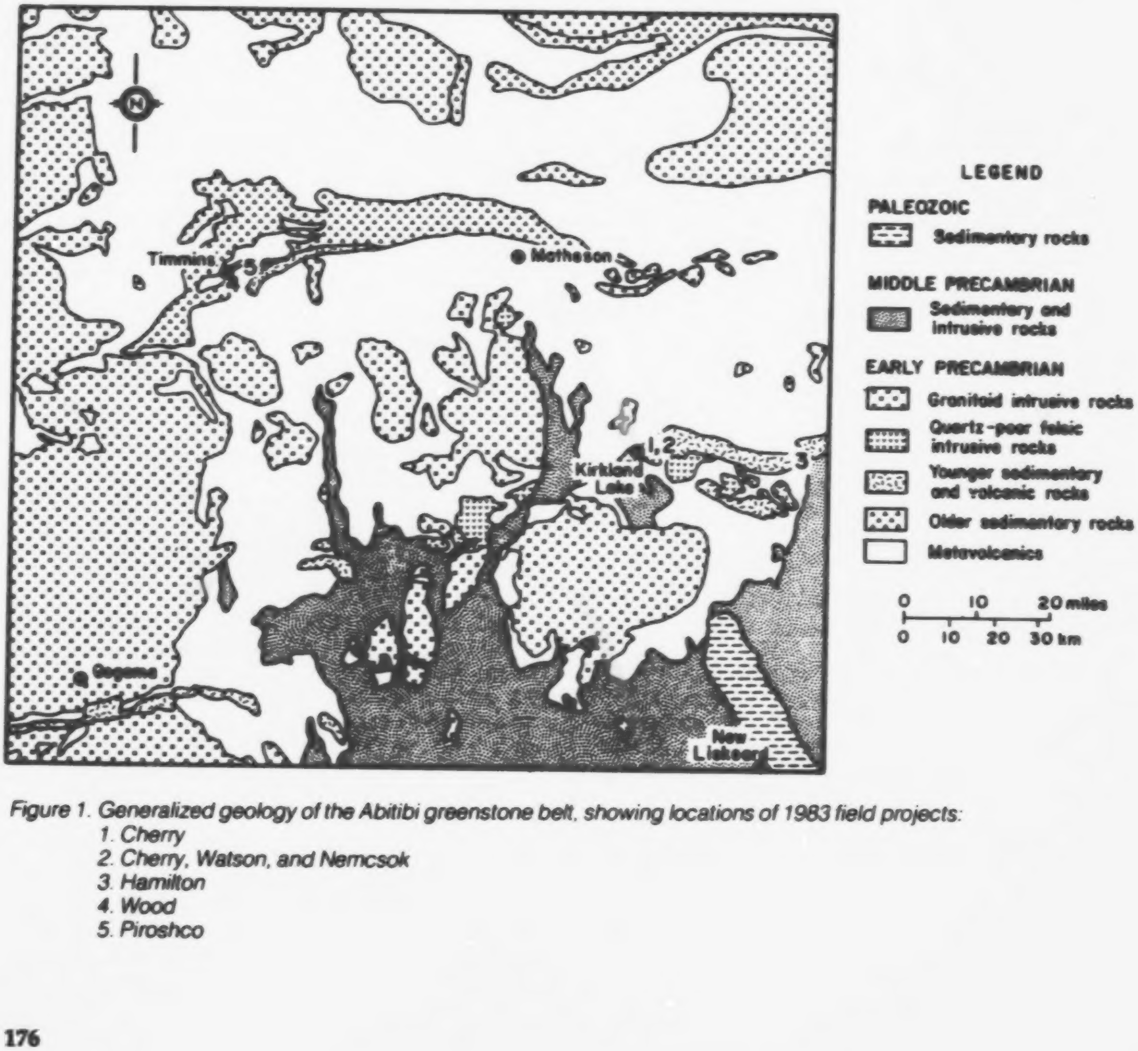
N
Timmins
5
Matheson
1, 2
3
Kirkland Lake
Gogama
New Liskeard
LEGEND
PALEOZOIC
Sedimentary rocks
MIDDLE PRECAMBRIAN
Sedimentary and intrusive rocks
EARLY PRECAMBRIAN
Granitoid intrusive rocks
Quartz-poor felsic intrusive rocks
Younger sedimentary and volcanic rocks
Older sedimentary rocks
Metavolcanics
0 10 20 miles
0 10 20 30 km

Figure 1. Generalized geology of the Abitibi greenstone belt, showing locations of 1983 field projects:

1. *Cherry*
2. *Cherry, Watson, and Nemcsok*
3. *Hamilton*
4. *Wood*
5. *Piroshco*

No. 39 The Macassa Mine, Kirkland Lake

M.E. Cherry[1], G.P. Watson[1], and G. Nemcsok[2]

Introduction

Two studies of the Macassa Mine at Kirkland Lake were initiated by the Mineral Deposits Section during the 1983 field season, as components of a comprehensive investigation of gold deposits in Ontario (Colvine 1983). One study (by M.E. Cherry) will examine the petrography and petrochemistry of syenites in the mine, and the relationship of these rocks to gold mineralization. The second study (by G.P. Watson and G. Nemcsok) will produce a new compilation of the geology and mineralization of the mine, incorporating developments in the mine since publication of the last such description (Charlewood 1964).

The Macassa Mine, which in 1983 is celebrating 50 years of continuous production, had produced 2 588 393 ounces of gold to the end of 1981, and has been the only active mine in the Kirkland Lake gold camp since 1968. This mining camp, which comprised 7 contiguous producing mines during its heydays in the 1930s and 1940s, had produced some 16 916 000 ounces of gold by 1949 (Thomson *et al.* 1950). The Macassa Mine remains the only access for extensive investigation of the geology and mineralization of this major gold camp, although the re-opening of the Lake Shore Mine in 1983 and the planned re-opening of the Wright-Hargreaves Mine by Lac Minerals Limited may eventually allow examination of more of the camp.

The only published comprehensive study of the geology of the Kirkland Lake area is that of Thomson (1950). The geology of each of the 7 mines at Kirkland Lake, including the Macassa Mine (Ward and Thomson 1950), was described in a series of companion reports (Thomson *et al.* 1950) to that publication. Other published studies of the Macassa Mine are those of Charlewood (1964), who described development from 1948 to 1964, and Watson and Kerrich (1983), who described ore types and documented hydrothermal regimes in the mine.

Petrography and Petrochemistry of Syenites

The geology of the Macassa Mine is a result of complex interaction among rock types, faulting, alteration, and mineralization. Gold occurs in all rock types in the mine (G. Nemcsok, personal communication, 1983), which include Timiskaming Group conglomerates, wackes, and tuffs, and syenites that have intruded them. Three ore types have been identified (Watson and Kerrich 1983); all are close to the faults and shear surfaces that occur throughout the mine. The host rocks adjacent to mineralization are highly altered; quartz, as veins, cement in breccia, and as replacement in altered rocks, is abundant.

Syenites are an important host to gold mineralization in the mine. The petrography and petrochemistry of these rocks, their alteration, and their relationship to faulting, are to be examined as part of a continuing study (Cherry 1982, 1983) of the relationship of felsic intrusions with lode gold deposits in Ontario. Marmont (1983) has reviewed the possible genetic significance of this association, and Hodgson (1983) has demonstrated its empirical significance to assessment of exploration targets in the Abitibi "greenstone belt" in Ontario.

During the 1983 field season, the syenites in the mine were examined and sampled in cross-cuts that extend to the north (Casakirk Cross-cut) and south (Amalgamated Kirkland Cross-cut) of the No. 1 Shaft on the 3000-foot level. These cross-cuts present a 1400 m long section that is almost perpendicular to the regional lithological and structural trends and exposes all rock types in the mine, shear surfaces that are important to mineralization elsewhere in the mine, and altered zones in the syenites. Although themselves only sparsely mineralized, the cross-cuts are illustrative of the geology of the mine.

The syenites comprise augite syenite, syenite, and porphyritic syenite. Fresh augite syenite is grey, has a medium- to coarse-grained hypidiomorphic texture, and contains abundant 1 to 2 cm long, rectangular, chloritic pseudomorphs of augite phenocrysts. Fresh syenite is also grey and has an hypidiomorphic texture; it, however, has no phenocrysts and usually is somewhat finer grained than the augite syenite. Syenite and augite syenite display equivocable relative age relationships and may be consanguineous and penecontemporaneous in their emplacement. Syenite and augite syenite alter to dark green chloritic rocks that retain original igneous textures. Fresh porphyritic syenite is grey, and characteristically contains abundant, rectangular (1 cm long), white feldspar phenocrysts and angular to ovoid chlorite-rich xenoliths (from 1 cm to 10 cm long) in a fine- to medium-grained hypidiomorphic groundmass. The porphyritic syenite occurs in the Macassa Mine as dikes and sills that intrude all other rock types. it is host to mineralization in the mine. Determination of absolute age of the porphyritic syenite is in progress (Marmont this volume). The porphyritic syenite alters to a brick-red colour, probably indicative of hematitization. Intense alteration masks the feldspar phenocrysts, and such porphyritic syenite is distinguished from similarly altered tuffs by the presence of the chloritic xenoliths. In many places, alteration of the porphyritic syenite appears to be associated with chloritic shear surfaces and "breaks", and with quartz veining. Similar alteration is intimately associated with orebodies elsewhere in the mine.

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[2] Area Chief Geologist, Macassa Division, Lac Minerals Limited, Kirkland Lake, Ontario.

The petrography and petrochemistry of both fresh and altered syenites will be determined in an attempt to determine the genesis and emplacement of the syenite magmas and the alteration processes that have affected them. Alteration is intimately associated with mineralization and documentation of the alteration processes is essential to understanding the sequence of events which led to the formation of the deposit.

Compilation Studies

The last published description of the geology and mineralization of the Macassa Mine is that of Charlewood (1964). Work in the mine over the last 19 years has obviously amassed large amounts of new information on ore types, ore grades, ore distribution, continuity of structures and lithologies, mineral associations, and innumerable other features of the mine. For example, breccia ore, which occurs in more recent, deep workings in the western part of the mine, was unknown in the mine in 1964. Since 1980, this ore type has provided over 40% of unbroken ore reserves (Watson and Kerrich 1983). The compilation work in progress will produce new geological plans and sections of the mine and detailed descriptions of orebodies, structural complexities, and other pecularities of the mine. Knowledge and understanding of these features is essential to understanding the Macassa Mine, and important to any discussion of the geology of lode gold deposits in Ontario.

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No. 40 Geological Study of the Area of the Kirkland Lake-Larder Lake Break in Central McGarry Township

J.V. Hamilton[1]

Introduction

Structural and stratigraphic relationships along the Kirkland Lake-Larder Lake break, and the geological controls and timing of associated gold mineralization, have been the subjects of continuing study and considerable controversy for more than 50 years. Major contributions to this controversy have been made by Thomson (1943, 1946), Ridler (1970), Jensen (1978), Downes (1979, 1981), and Jensen and Langford (1983).

The most detailed mapping of the area was by Thomson (1943). He assigned volcanic rocks in the northern part of the area, comprising felsic and mafic lava flows and associated pyroclastic rocks, to the Keewatin series, and classified an east-trending belt of younger sedimentary and volcanic rocks in the southern part of the area as part of the Timiskaming series. Thomson (1943) noted that although certain mafic lavas in the Timiskaming series are similar in appearance and composition to those in the Keewatin series, they occur at different stratigraphic horizons and, consequently, are of different ages. Later, Thomson (1946) documented an angular unconformity between the Keewatin and Timiskaming series in the Kirkland Lake area, but noted that this contact is conformable in the Larder Lake area, due to coincidence of structures. Thomson interpreted the Kirkland Lake-Larder Lake break as a reverse fault of large displacement with the south side thrust upward.

Ridler (1970) suggested substantial revisions to Thomson's stratigraphic and structural interpretations of the district, using Goodwin's (1965) concept of volcanic cycles and related iron formations. The key aspect of Ridler's study was recognition of carbonate facies iron formation among the carbonate rocks of the Kirkland Lake-Larder Lake break. The existence of the break was thereby thrown into question.

Jensen and Langford (1983), in a regional stratigraphic study that made extensive use of major element compositions of the volcanic rocks, suggested that 2 complete volcanic cycles are preserved in the area, each having a basal komatiitic, middle tholeiitic, and upper calcalkalic sequence. A differentiation trend from mafic or ultramafic to more felsic rocks was defined within each sequence. Mapping by Jensen (1978) indicated the possibility that 2 sedimentary groups are present in the area. To the south of the Kirkland Lake-Larder Lake break, sedimentary units are conformable(?) and interlayered with subalkaline mafic volcanic rocks, while north of the break, the sediments are interlayered with alkaline volcanic rocks and may be unconformable on subalkaline volcanic rocks. This definition of stratigraphy re-established the break as a major structural discordance. The sedimentary and volcanic rocks south of the break were tentatively named the Larder Lake Group, and the sediments and alkalic volcanic rocks north of the break, interpreted to be younger, were redefined as the Timiskaming Group by Jensen and Langford (1983). The tholeiitic succession north of the break was named the Kinojevis Group.

Downes (1979, 1981) distinguished 2 discordances in the Virginiatown area. Discordance A, which separates alkalic volcanic rocks and associated sedimentary rocks from a sequence of turbidites and mafic and ultramafic volcanic rocks to the south, constitutes both a lithological and a structural discordance. Downes interpreted the Kirkland Lake-Larder Lake break to be a structural discordance (Discordance B), separating 2 domains with opposite plunging fold axes. Lithologies on either side of the break would then be stratigraphically related.

The purpose of the present study, which was initiated in 1983 with detailed mapping in McGarry and McVittie Townships, is to attempt to resolve some of these controversies about structural and stratigraphic relationships near the Kirkland Lake-Larder Lake break. Resolution of these problems should allow identification of geological controls on gold mineralization in the area.

General Geology

Map units, shown on the accompanying sketch of the geology of the area mapped in 1983 (Figure 1), were defined as:

1. Ultramafic (and Associated Mafic) Volcanic Rocks

Rocks of this map unit are generally black or dark green to grey on fresh surfaces, and weather to shades of rusty brown, green, and grey. Komatiitic members, which are distinguished by their spinifex textures, are tabular flows up to 15 m thick. Several fragmental and flow-top breccia horizons were observed in and west of the Kerr Addison

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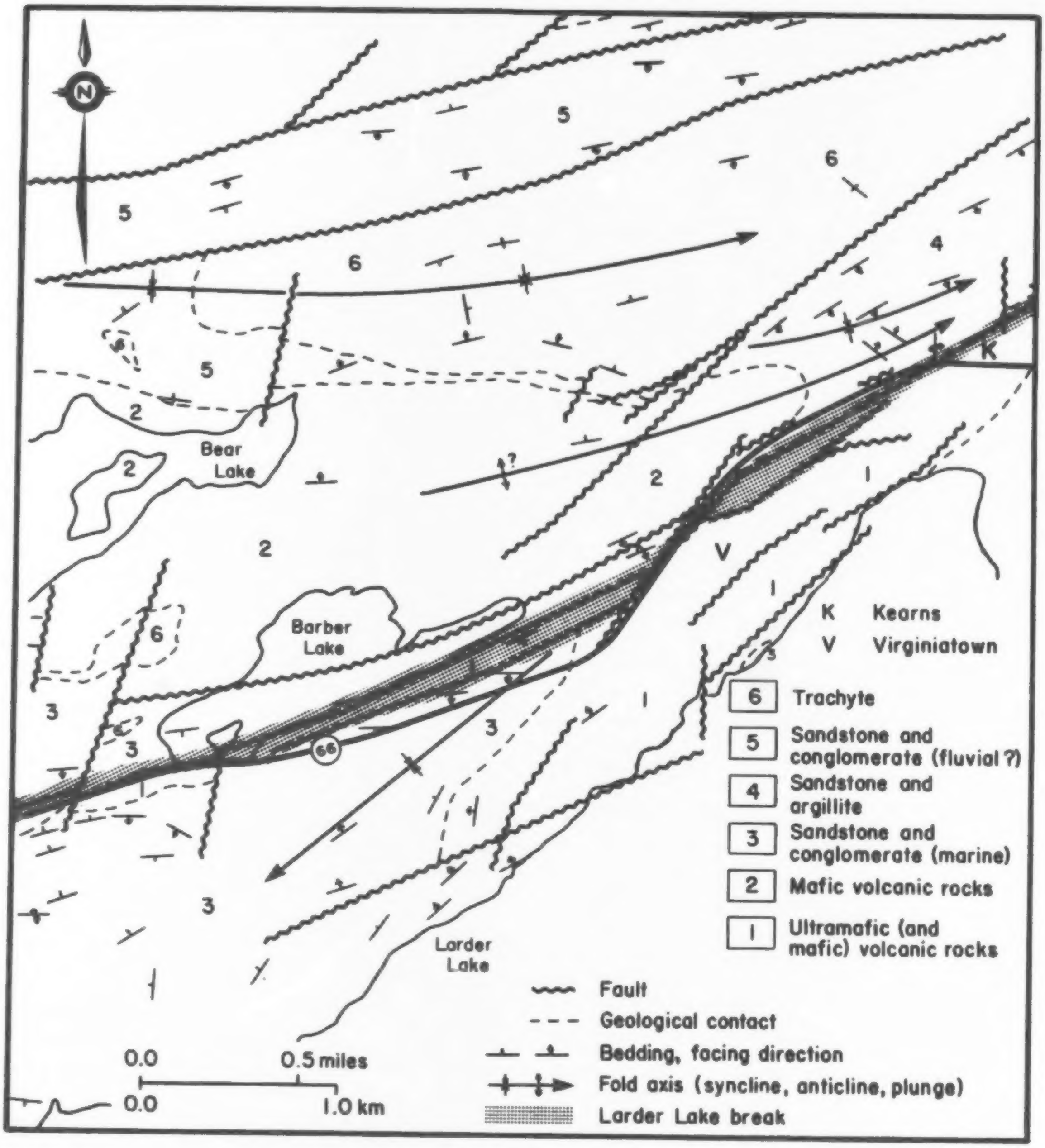
5
5
6
6
4
5
2
2
Bear Lake
2
2
?
V
1
1
K
6
Barber Lake
3
3
?
3
1
66
3
Larder Lake
K Kearns
V Virginiatown
6 Trachyte
5 Sandstone and conglomerate (fluvial ?)
4 Sandstone and argillite
3 Sandstone and conglomerate (marine)
2 Mafic volcanic rocks
1 Ultramafic (and mafic) volcanic rocks
Fault
Geological contact
Bedding, facing direction
Fold axis (syncline, anticline, plunge)
Larder Lake break
0.0
0.5 miles
0.0
1.0 km
N

Figure 1. Geology of central McGarry Township, showing major units, structures, and facing directions. Geology by J.V. Hamilton (1983), after Thomson (1943).

Mine. Much of the rock within this map unit is extensively altered due to shearing, faulting, and subsequent carbonatization along or adjacent to the faulted zones. The most extensively carbonatized lithology has an ultramafic composition; this gives an apparent stratiform distribution to the carbonate rocks.

2. Mafic Volcanic Rocks

Rocks in this unit are fine to medium grained, magnetic to non-magnetic, dark green to grey on fresh surfaces, and dark to light green and grey on weathered surfaces. They usually occur as massive flows with primary structures such as vesicles and pillows. Pillowed flows up to 20 m thick were found, but could not be traced with certainty over large areas.

3. Sandstone and Conglomerate (Marine)

The conglomerate in this map unit is polymictic, shows graded bedding at several localities, and is interbedded with or grades into sandstone. It can be clast- or matrix-supported. Pebbles are dominantly of mafic to felsic volcanic rocks, with numerous chert and vein quartz clasts. Jasper pebbles are rare to absent, in contrast with their frequent occurrence in fluvial(?) conglomerate north of the Kirkland Lake-Larder Lake break. The sandstone in this unit is generally fine to medium grained, shows graded bedding, and is interbedded with fine-grained argillite. This unit may be of turbiditic origin.

4. Sandstone and Argillite

This unit comprises interbedded fine- to medium-grained, grey to green sandstone, and dark grey to black argillite. Sandstone beds range up to 2 m in thickness, are typically sharp-based, and generally display graded bedding and, locally, parallel lamination or ripple cross-lamination. Sedimentary structures, such as load casts and flame structures, occur in less deformed areas along with rip-up mud clasts. Well developed but incomplete Bouma sequences suggest that these rocks are turbidites.

5. Sandstone and Conglomerate (Fluvial?)

The sandstone of this map unit is generally green to grey and medium to coarse grained. It has cross-stratification and commonly contains scattered pebbles. The conglomerate is polymictic and clast supported, with beds of variable thickness. Mafic and felsic volcanic rocks predominate as clasts, with lesser syenite, jasper, quartz-feldspar porphyry, chert, vein quartz, and iron formation pebbles. Hyde (1980) has interpreted this unit as being a braided river deposit.

6. Trachyte

This unit is a heterogeneous assemblage of rocks, including pyroclastics, flows, tuffs, and breccias. These rocks are usually characterized by a red-purple to pinkish colour. Massive trachyte is fine to medium grained; varying degrees of porphyritic texture are developed in the trachyte. Breccia and pyroclastic members consist of a fine-grained mafic trachytic matrix, and angular to rounded, coarse-grained, porphyritic trachyte fragments. Tuffs are fine to medium grained, water-sorted, thinly bedded horizons.

Structural Geology

The dominant structure in the area is the Kirkland Lake-Larder Lake break, which displays evidence of both ductile and brittle deformation. At the Kerr Addison Mine the break is a shear zone and not a narrow, discrete fault. The shear zone includes a talc-chlorite schist and a green carbonate unit that together are approximately 130 m in width. Parallel shear zones and chlorite slip surfaces in mafic volcanic rocks away from the break indicate that the shearing affected an even greater width. Slickensides within the shear zone suggest that at least 3 different directions of movement affected the bounding blocks of rock. Carbonatized ultramafic rocks are associated with the break and occur as clasts within the sedimentary rocks in the area. This implies that movement within the zone of the break was long lasting and periodic, with a history of changing stress conditions. At least 1 important period of brittle deformation postdated carbonatization at the Kerr Addison Mine, brecciating the carbonate mass and allowing development of quartz veins which host some of the gold ore.

North of the Kirkland Lake-Larder Lake break, map units 5 and 6 (Figure 1) are folded into a steeply east-plunging syncline, which is truncated to the east by a northeast-trending fault. South of this fault, map unit 2 narrows to the east and facing directions here are indicative of an anticline. Sedimentary rocks of unit 4 to the east are folded into a tight sequence of anticlines and synclines and appear to be drag-folded and gradationally deformed into the main shear zone. Sandstone beds are rapidly thinned where they are deflected into the break, suggesting a high degree of flattening across the zone. At several locations north of Kearns the sedimentary beds are truncated at a high angle. The overall form of the folds as they bend into the shear zone indicates a sinistral component to movement on the break.

South of the Kirkland Lake-Larder Lake break, the main structure appears to be a syncline with a moderately southwest-plunging axis. This syncline is cut by several faults, including the main shear zone which truncates the northern limb of the syncline (Figure 2). South facings across the shear zone are abundant in the central region of Figure 1, but to the east, facings are back to back.

The Timiskaming-Keewatin contact, documented by Thomson (1946) as an unconformity near Kirkland Lake, was traced in the Virginiatown area and found to be a sheared, carbonatized contact, strongly indicating a fault

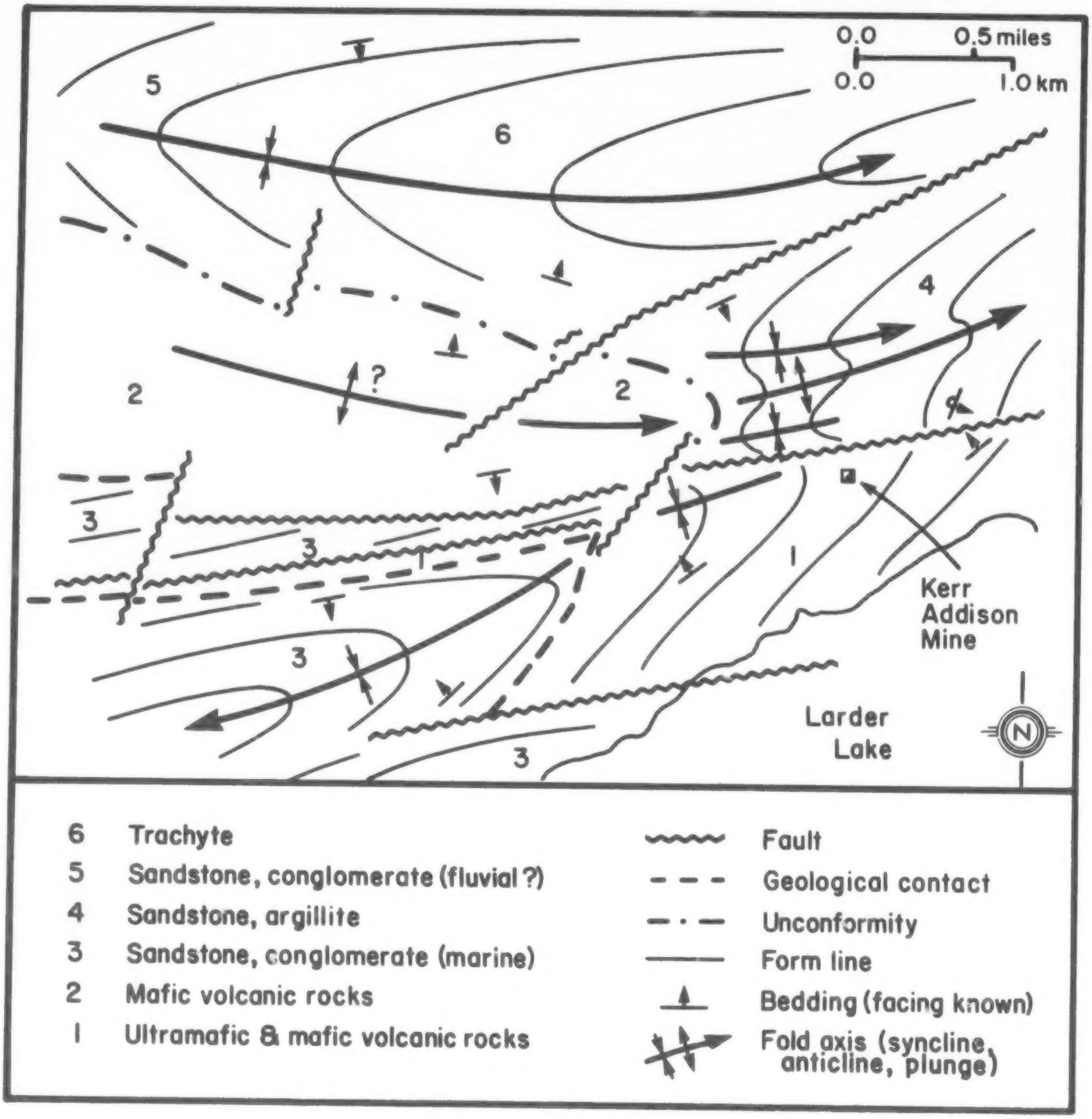
0.0
0.5 miles
0.0
1.0 km
5
6
4
2
2
3
3
3
3
1
Kerr Addison Mine
Larder Lake
N
6 Trachyte
5 Sandstone, conglomerate (fluvial ?)
4 Sandstone, argillite
3 Sandstone, conglomerate (marine)
2 Mafic volcanic rocks
1 Ultramafic & mafic volcanic rocks
Fault
Geological contact
Unconformity
Form line
Bedding (facing known)
Fold axis (syncline, anticline, plunge)

Figure 2. Schematic representation of structure, with form lines, showing the limb fault along the northern limb of the major syncline south of the Kirkland Lake-Larder Lake break.

contact rather than an unconformable contact. This fault may coincide with a major shear zone, subparallel to the Kirkland Lake-Larder Lake break, mapped by the author in sedimentary rocks just north of Highway 66 near the Kerr Addison Mine. This sedimentary-volcanic horizon was observed in a pit north of the rail line in central McGarry Township, where it also appeared to be highly sheared.

Three sets of cleavages have been distinguished in the area. The earliest cleavage (S_1) is a striped banding in argillaceous beds at some outcrops. The banding is interpreted as a pressure solution feature associated with early development of the cleavage. No major structures yet recognized have been related to this cleavage. The second cleavage (S_2) is a continuous cleavage defined by sericite-chlorite fabric in slaty beds. This fabric penetrates coarser sandstone beds where schistosity is represented by dimensional orientation of both micaceous and granular minerals. The S_2 cleavage is found in all units in the area and is best developed in sandstone and slate units where cleavage is refracted up to 30° when traced from sandstone to slate beds. It was generally found that this cleavage is axial planar to large-scale folding in the region and is widespread outside the zone of influence of the Kirkland Lake-Larder Lake break. The third cleavage (S_3) is a disjunctive, spaced cleavage with discrete parallel surfaces separating less cleavable zones (microlithons). Cleavage surfaces are pressure solution surfaces, marked by dark minerals (less mobile?), which separate bands of more siliceous rock. Where this cleavage is well developed bedding becomes partially transposed into the cleavage plane. This fabric is local in nature, seems to be strongest near areas of intense shearing, and is probably related to stresses associated with movement in the break.

In areas near the Kirkland Lake-Larder Lake break, physical disaggregation of clastic beds is a common feature. Fine-grained clasts of original argillaceous beds, similar to mud chip clasts, are oriented parallel to subparallel to cleavage. At other locations, flame structure and fine-grained lenses are also aligned parallel to cleavage. In those cases where clasts from fine-grained clastic horizons appear to have been moved in a direction parallel to cleavage, the disaggregation may be related to an early diagenetic event or to a hydromechanical disaggregation of beds during cleavage formation. However, within the shear zone itself, the separation of fine-grained beds into *en echelon*lenses and pods is a function of shearing.

Preliminary Conclusions

1. Facings in mafic volcanic and sedimentary units along the Kirkland Lake-Larder Lake break suggest that the main structural feature south of the break is a truncated syncline (Figure 2) with a moderately southwest-plunging axis. The Kerr Addison Mine sits roughly within the hinge of this major structure.

2. The Kerr Addison Mine also appears to lie within a splay of the Kirkland Lake-Larder Lake break, near the intersection of this major structure with a northwest-trending belt of felsic intrusions in the Keewatin basement. Anomalous zones of mineralization are also found along this northwest trend, which roughly parallels, and nearly coincides with, the eastern boundary of the Lake Timiskaming Rift Valley, as documented by Lovell and Caine (1970).

3. The "Keewatin-Timiskaming" contact in the Barber Lake area is sheared and carbonatized and is interpreted as a fault contact, as opposed to the unconformable contact documented in the Kirkland Lake area by Thomson (1946).

4. Carbonatization within sedimentary rocks increases with proximity to the Kirkland Lake-Larder Lake break, suggesting that carbonatization was contemporaneous with development of the break. Carbonatization was also observed along faults cutting mafic volcanic rocks and associated with quartz veining in trachytic rocks north of Virginiatown. These cross-cutting relationships, and the intimate association of carbonate-rich rocks with faults, discourages the theory that the carbonate was originally of sedimentary origin.

5. Three sets of cleavages have been recognized in the map area. S_2 fabric is axial planar to major folds in the area, while S_3 may be related to a later compressional event associated with movement on the break.

6. Rocks mapped as slate and wacke (Thomson 1943) immediately west of Barber Lake include significant units of unmapped conglomerate and trachyte. These units are south of Downes' (1979) structural Discordance A and therefore conflict with his stratigraphic interpretation south of the discordance.

7. According to Jensen and Langford (1983), there are no komatiitic lavas within the tholeiitic Kinojevis Group volcanic rocks. However, spinifex texture has recently been reported from volcanic rocks within the Kinojevis Group north of the rail line in central McGarry Township (H.A. Lee, Geo-Indicators Limited, personal communication, 1983). If there are komatiitic rocks within the Kinojevis Group, then the contact between the Kinojevis and Larder Lake Groups is uncertain and the relationship of the Timiskaming rocks to mafic volcanic rocks in the area remains unclear.

This project will continue in the 1984 field season, when structural and stratigraphic mapping will be extended into Hearst, Gauthier, Lebel, and Teck Townships. The expansion of the map area will allow the documentation of the large-scale deformation associated with the Kirkland Lake-Larder Lake break and any relationship this may have with gold mineralization in this area.

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No. 41 A Re-appraisal of the Geology of the Coniaurum Mine, Tisdale Township

D.W. Piroshco[1]

Introduction

In spite of the long history of geological study of the Porcupine Camp, the second largest gold mining camp in the world, several key aspects of the geological history, relating gold mineralization to structure, stratigraphy, and porphyry intrusions, remain poorly understood (Hodgson 1983). The main emphasis of this study is to determine: a) the relationship of carbonate (ankerite) alteration zones, shear zones, and quartz vein lodes to stratigraphy and east-plunging 'S'-shaped folds (i.e. the Coniaurum anticline); and b) the relationship of planar and linear fabric with the S-shaped folds. The Coniaurum Mine area was chosen for study because of its low degree of geological complexity relative to the Hollinger and McIntyre Mines, the presence of the Coniaurum anticline, and the abundance of surface outcrops.

The Coniaurum Mine covers the eastern extension of the Hollinger-McIntyre Mines gold ore zone in the Timmins area. Ferguson (1968) and Pyke (1982) have provided the most recent and comprehensive overviews of the regional geology and ore deposits of Tisdale Township. The mining history and a description of lithologies, general structure, and ore zones of the Coniaurum Mine are presented by Carter (1948) and by Ferguson (1968). Approximately 1 053 594 ounces of gold and 186 714 ounces of silver were produced from 4 203 502 tons of ore in the Coniaurum Mine between 1928 and 1959. The property is currently being re-evaluated by Pamour Porcupine Mines Limited.

Description of Field Work

Geological surface mapping, carried out at a scale of 1:2400, was confined to an area of approximately 2.6 km^2, which roughly corresponds to the southern half of the Coniaurum anticline (Figure 1). A grid was established throughout this area, as an aid for mapping. Areas to the north and west are covered by extensive accumulations of mine tailings. Underground workings were inaccessible.

Recently exposed outcrop (approximately 100 by 50 m) over the Main Shaft area at the Davidson-Tisdale gold Property (Ferguson 1968), located about 4.5 km east-northeast of the Coniaurum Property, and the 400 Open-Pit at the Hollinger Mine, located approximately 3.7 km west-southwest of the Coniaurum Mine, were also examined and sampled in detail. This examination was to further document the relationship of quartz veins, alteration, and shear zones to stratigraphy and porphyry intrusion. The results of this work are not discussed in this summary.

Preliminary Results

The south limb and the hinge area of the Coniaurum anticline and a smaller scale S-shape fold to the southwest were examined in detail. Both of these gold structures appear on Coniaurum Mine underground plans. The stratigraphy consists of a complex series of 060° striking, steeply south dipping (70°), south facing, mafic volcanic flows, which are of an irregular, lensoidal nature. Individual flows can be distinguished by the presence or absence of pillows, varioles, and amygdules. In cases where textural criteria are absent, flow contacts are locally marked by narrow zones (<0.5 m) of bleaching, carbonatization, and quartz veining. Otherwise, flow tops are discernible by semicontinuous horizons of flow-top breccia or hyaloclastite, and by thin (1 to 3 m) semicontinuous beds of carbonaceous sediment.

Directly overlying the mafic volcanic rocks are felsic calc-alkalic pyroclastic rocks, referred to as the Krist Fragmental Unit by Ferguson (1968). Outcrops of the Krist Fragmental Unit are found in the far east-central portion of the Coniaurum Mine.

Heterolithic breccias, similar to some parts of the Krist Fragmental Unit, crop out in various locations on the property. These breccias occur as 1 to 5 m wide, north-northwest-trending dikes which clearly cross-cut stratigraphy, and as narrow, discontinuous lenses (<15 cm wide), parallel to stratigraphy but spatially related to an intrusive quartz-feldspar porphyry stock (the Coniaurum porphyry). On underground plans (400-foot level) and in diamond-drill core examined this summer, these breccia bodies also occur locally as gradational units marginal to the Coniaurum porphyry and as linear, discontinuous zones parallel to stratigraphy, but also spatially related to the porphyries. The breccias consist of angular to subrounded fragments of chloritized mafic volcanic rock,

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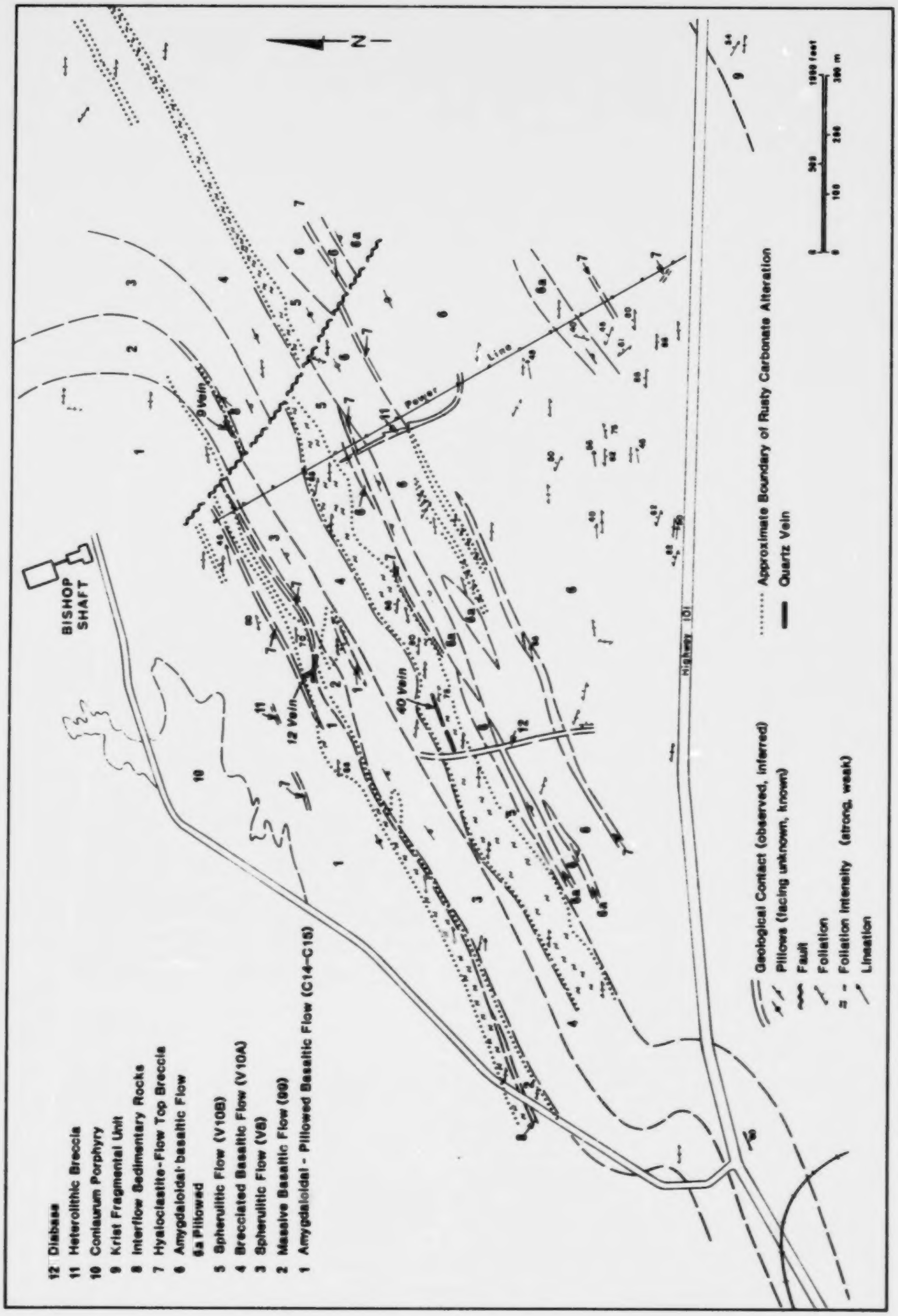
12 Diabase
11 Heterolithic Breccia
10 Coniaurum Porphyry
9 Krist Fragmental Unit
8 Interflow Sedimentary Rocks
7 Hyaloclastite-Flow Top Breccia
6 Amygdaloidal basaltic Flow
6a Pillowed
5 Spherulitic Flow (V10B)
4 Brecciated Basaltic Flow (V10A)
3 Spherulitic Flow (V8)
2 Massive Basaltic Flow (99)
1 Amygdaloidal - Pillowed Basaltic Flow (C14-C15)
Geological Contact (observed, inferred)
Pillows (facing unknown, known)
Fault
Foliation
Foliation Intensity (strong, weak)
Lineation
Approximate Boundary of Rusty Carbonate Alteration
Quartz Vein
BISHOP SHAFT
N
9 Vein
12 Vein
40 Vein
Power Line
Highway 101
1000 feet
300 m

Figure 1. Geology of the Coniaurum Mine (geology by D.W. Piroshco).

quartz-feldspar porphyry, and fuchsite in a fine-grained, dark green, chloritic matrix.

Shear zones, trending 065° and dipping 73° south, are less than 70 m wide, and are characterized by a well developed, roughly east-trending foliation and by intense, rusty carbonate (ankerite) alteration. The quartz bodies generally trend 065° to 075°, have associated pyritic envelopes and cross-cut flow contacts, Coniaurum porphyry, and the foliation in the shear zones. On the south limb of the Coniaurum anticline, the shear zones are oriented parallel to the stratigraphy and are in most cases developed along flow contacts or within individual, incompetent flows in zones of complex stratigraphy. Shearing and quartz vein lodes cross-cut the Coniaurum anticline. This is clearly shown on mine underground plans.

Quartz veins, with associated rusty carbonate alteration envelopes, are also found in a massive, relatively competent (unsheared) Fe-tholeiite (Pyke 1982), termed the '99' flow by mine geologists. This is the most important host for ore bodies in the mine and is recognized by the presence of buff leucoxene phenocrysts. Quartz lodes within the '99' flow are oriented oblique to the flow contacts and occur in *en echelon*arrays.

Examination of planar fabric on the hinge and limb areas of the Coniaurum anticline indicates that 2 fabrics are folded with flow units which outline the anticline. An east-trending fabric, axial planar to the fold, cross-cuts these 2 fabrics. The relationship of these 2 early fabrics to macroscopic structures in the Timmins area is at present undetermined.

Future Work

Future work will involve:

1. a complete petrographic description of lithological units and alteration types at the Coniaurum Mine and Davidson-Tisdale Property
2. a microfabric analysis using oriented thin sections from the Coniaurum Mine and Davidson-Tisdale Property. The significance of the fabric analysis will depend on whether or not the fabrics can be related to other megascopic structures in the Porcupine Camp (i.e. Porcupine Syncline, Kayorum Syncline, Ancestral Hollinger Fault).
3. determination of the relationship of the heterolithic breccia units and porphyry intrusions to gold mineralization by determining the precious metal and trace element content of the fragments and matrix independently. Field relationships suggest a genetic link between the porphyry intrusions and breccia units.
4. a documentation of the relationships between shear zones, alteration, and quartz veining at the Davidson-Tisdale Property and a comparison with the Coniaurum Mine

Summary

The field study has indicated the following:

1. Heterolithic breccia units containing quartz-feldspar porphyry fragments cross-cut stratigraphy and show a close association with an intrusive quartz-feldspar porphyry stock (the Coniaurum porphyry).
2. An east-trending foliation, axial planar to the Coniaurum anticline, cross-cuts 2 earlier foliations. The relationship of these 2 early fabrics with other mesoscopic structures in the Timmins area is undetermined at this time.
3. Shear zones, with associated rusty carbonate alteration and quartz bodies, parallel the general trend of stratigraphy, but cross-cut the S-shaped folds.
4. Gold mineralization is spatially associated with the '99' flow, which is a thin massive unit, and with rusty shear zones that occur in the spherulitic flow (Map Unit 5, Figure 1). Mineralization in both these units may be controlled, in part, by ductility contrasts between these units and the surrounding rocks.

Acknowledgments

Pamour Porcupine Mines Limited allowed access to the Coniaurum Mine, the mapping and sampling of surface outcrop, and the compilation of relevant geological data. P.C. Walford, Chief Area Mine Geologist, is thanked for his guidance, support, and co-operation. J. Kirwan, Consulting Geologist for Davidson-Tisdale Mines Limited, is thanked for allowing work to be carried out at the Davidson-Tisdale Property. This field work is part of an M.Sc. research program at Queen's University under the supervision of C.J. Hodgson.

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No. 42 Controls on Tungsten (Scheelite) Mineralization in the Hollinger-McIntyre Gold Vein System, Timmins

Peter C. Wood[1]

Introduction

The first substantial production of tungsten from the Canadian Shield came from the Porcupine Camp, from which scheelite was intermittently produced from 1940 to 1953. This production amounted to some 445 502 lbs of contained tungsten trioxide, of which the Hollinger Mine (now known as the Timmins Underground Project of Pamour Porcupine Mines Limited) was responsible for approximately 80 % (Table 1). Little, however, is known about the mode of occurrence, economic value or genetic significance of the scheelite mineralization found in Archean gold deposits, despite the fact that it is common in many of these deposits (e.g. Hollinger-McIntyre, Sigma-Lamaque, Dome and Campbell Mines).

General Geology

The Hollinger-McIntyre area is underlain by a series of tightly folded volcanic rocks (Keewatin) with thin-bedded carbonaceous interflow sediments which have been intruded by stocks of quartz porphyry. The structure of the area is very complex but 2 periods of folding can be defined. An original north-trending series of folds was subsequently refolded about an east-northeast axis. The porphyries and enclosing rocks have a uniform plunge of 45° to 50°, striking 080°.

Observations of the porphyries indicate that a high state of strain was imposed in the upper levels of the mines, and that the porphyries were extensively altered to quartz-sericite schists. At deeper levels, both the porphyries and volcanic rocks are intruded by a series of albitite dikes which Langford (1941) indicates have a lesser, intermediate, strain state than the porphyries. Both the porphyries and albitite dikes are cross-cut by the gold-bearing quartz veins which are, in comparison, essentially unstrained.

All rocks, with the exception of the albitite and later diabase dikes, have been highly altered by both dynamic and hydrothermal metamorphism.

Objectives and Progress-to-Date

The general objectives of this study are to:

1. Collect information which will evaluate whether or not tungsten could ever be an economic by-product of an Archean gold producer.
2. Define the controls on tungsten mineralization in order to help evaluate whether or not major scheelite deposits might be a valid exploration target in the Superior Province.
3. Evaluate the genetic significance of scheelite in Archean gold deposits in order to improve the geological concepts on which exploration for such deposits is based.

TABLE 1 **SCHEELITE PRODUCTION FROM THE PORCUPINE CAMP (after Ferguson 1968)**

		WO_3	
YEAR	MINE	POUNDS	kg
1940	Hollinger	812	368
1941	Hollinger	11 068	5 025
	Preston	742	337
	McIntyre	315	143
	Dome	62	28
1942	Hollinger**	102 902	46 717
	McIntyre**	567	257
	Dome**	10	4.5
1943	Hollinger**	233 807	106 148
	Preston	520	236
1944	Hollinger***	6 763	3 070
1952	Hollinger**	50 734	23 033
	Preston*	2 254	1 023
	Coniaurum	252	114
	Coniaurum*	209	95
	McIntyre*	234	106
1953	Hollinger	48 780	22 146
		445 502	202 258

Notes
* Estimated
** Low grade concentrate from Hollinger scheelite recovery plant upgraded in the United States
*** Production from Hollinger scheelite recovery plant

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[1] Graduate Student, University of Toronto, Toronto, Ontario

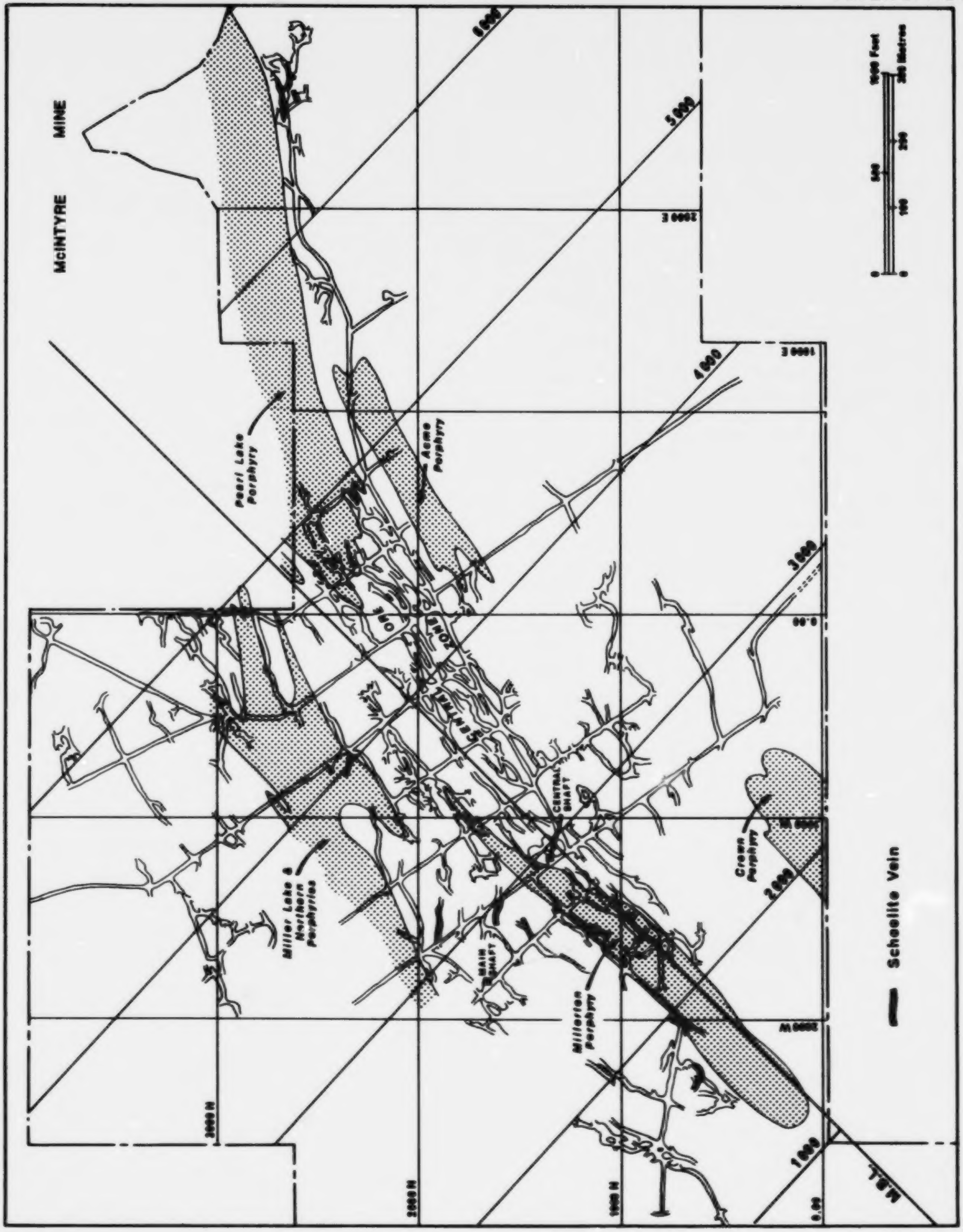
McINTYRE MINE
Pearl Lake Porphyry
Acme Porphyry
Miller Lake & Northern Porphyries
Crown Porphyry
Millerton Porphyry
MAIN SHAFT
CENTRAL SHAFT
Scheelite Vein
6000
5000
4000
3000
2000
1000
N.B.L.
2000 E
1000 E
0.00
1000 W
3000 N
2000 N
1000 N
0.00
0
100
200
300 Metres
500
1000 Feet

Figure 1. Map of the 1550-foot level, Hollinger Mine, showing the relationship of scheelite veins to porphyry intrusions

To this end, detailed mapping and sampling were done in 2 representative scheelite-mineralized stopes in the Hollinger Mine. These stopes, 15-08-01 and 18-83-01, are on the 1550-foot and 1850-foot levels respectively and are located in the Millerton porphyry.

Compilation of past Hollinger scheelite production data was also done and stope locations were plotted at a scale of 500 feet to 1 inch on level plans. This compilation confirmed a distinct spatial association of the scheelite mineralization with the Millerton and Pearl Lake porphyries, as previously noted by Allen and Follinsbee (1944) (Figure 1).

The samples will be used to examine and describe the petrology (transmitted/reflected light), mineralogy, paragenetic sequences, and associated wall-rock alteration. The petrologic and microthermometric properties of primary and secondary fluid inclusions in mineralized material will also be examined.

Keys (1940) suggested that all the scheelite in the Hollinger Mine is associated with the earliest stages of the mineralization process. However, from observations made this summer, it appears that the scheelite associated with the Millerton porphyry occurs in two forms. Early scheelite-rich veins, which are generally 7 to 10 cm wide, are composed mainly of scheelite with lesser quartz, ankerite, sericite, and pyrite. This scheelite is generally a brownish orange colour, coarse grained, and contains numerous quartz- and ankerite-filled fractures which are oriented perpendicular to the vein margins. A second phase of scheelite mineralization occurs as clots from 2 to 30 cm in diameter within larger quartz veins. This scheelite is a paler buff to sandy colour and appears to be co-genetic with the quartz of the main vein filling.

Allen and Follinsbee (1944) suggested that the scheelite and gold ore shows a semblance of zoning about the porphyries, with the gold to scheelite ratio rising rapidly with increasing distance from the intrusive centres. However, miners note an empirical relationship of higher ore grades where scheelite occurs. This relationship will be tested in the future, by sampling away from the porphyries.

Allen and Follinsbee (1944) and Quinn (1931), from observations based on reflected light petrography, have noted that gold sometimes occurs as a fracture filling in the scheelite and as small blebs along grain boundaries Keys (1940) suggested that the precipitation of gold in and around such minerals as the scheelite was in part due to the fact that these minerals produced a heterogeneous assemblage favourable for the formation of fractures under later stress and also in part due to varying degrees of control over the precipitation of gold. This too will be tested in the laboratory with transmitted and reflected light petrography.

Acknowledgments

Pamour Porcupine Mines Limited allowed mapping and sampling of the scheelite-bearing stopes in the Hollinger Mine and provided access to production records that identified these stopes. Mr. P.C. Walford, Chief Area Mine Geologist of Pamour Porcupine Mines Limited in Timmins, is thanked for his cooperation and advice. This work is part of an M.Sc. research program at the University of Toronto under the supervision of E.T.C. Spooner.

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Mining and Exploration Activities, and Gold Studies in the Beardmore-Geraldton Belt

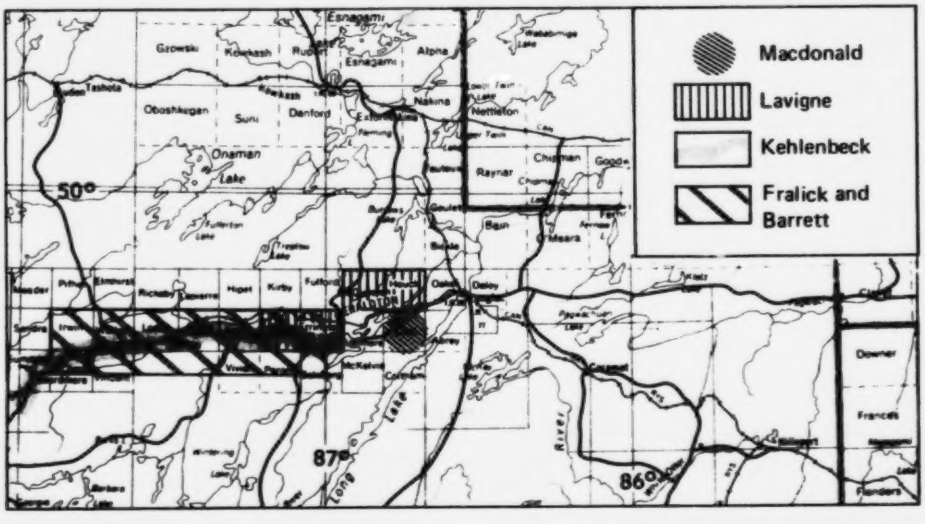
Introduction by J.K. Mason[1] and A. James Macdonald[2]

Major Exploration and/or Development Programs

Although the Beardmore-Geraldton area has not seen major gold production since the early 1970s, the scale of activity since 1980 has increased considerably. Mining Corporation of Canada Limited is in charge of development, mining, and milling at the Consolidated Louanna Gold Mine (Figure 1, location 1), O'Sullivan Lake. Teck Corporation, owner of the Leitch Gold Mine, is "involved in preliminary negotiations which could see that company use some of the capacity in the custom mill" (Northern Miner, June 23, 1983, p.5) of Pancontinental Mining (Canada) Limited, Beardmore, Ontario (Figure 1, location 2). Roxmark Mines Limited and Sherritt Gordon Mines Limited are re-evaluating the Magnet Consolidated Gold Mine, Errington Township (Figure 1, location 3). An exploration program of dewatering, sampling, mapping, and diamond drilling has been initiated. A headframe and hoist have been installed. Major diamond drill programs have been initiated by Dome Mines Limited (13 000 feet) on the Jellicoe Mine property, Lindsley Township (Figure 1, location 4) and by Metalore Resources Limited (20 000 feet) on the Brookbank Prospect, Irwin Township (Figure 1, location 5). These operations, and several dozen other exploration activities, will be described in more complete detail in the annual "Report of Activities, Regional and Resident Geologists", to be published in early 1984.

Gold Studies

In 1982 the Mineral Deposits Section of the Ontario Geological Survey began a study of gold mineralization associated with chemical sediments (Fyon *et al.* 1983; Macdonald 1982, 1983; Mason and McConnell 1983). The former producing Hard Rock and MacLeod-Cockshutt Mines near Geraldton (Figure 1, location 6) were studied



LOCATION MAP

Scale: 1: 1 584 000 or 1 inch to 25 miles

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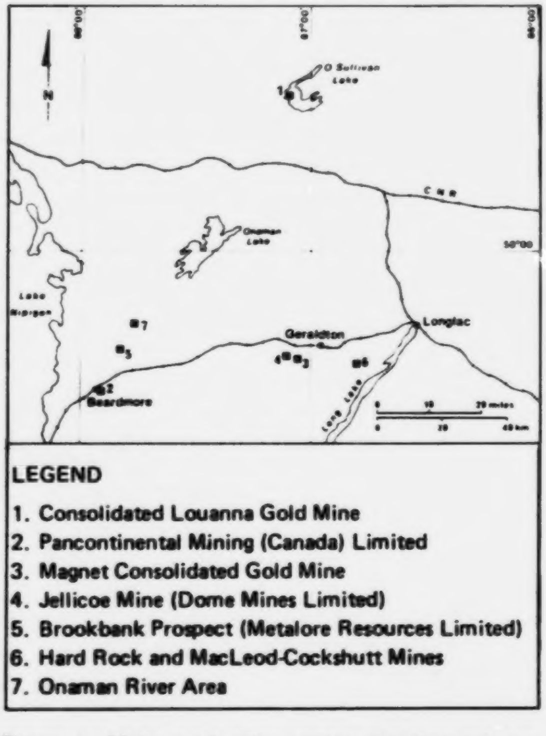
[2] Geologist, Mineral Deposits Section, Ontario Geological Survey, Toronto.

in detail (Macdonald 1982, 1983). As a result of this program, several geological factors were recognized, critical to the understanding of the geological environment in which the deposits formed and the nature of the mineralizing process. These include:

1. the sedimentology of units spatially associated with mineralization
2. deformation, both on a regional and deposit scale
3. alteration and degree of metamorphism, to define relationships with mineralization
4. source of the hydrothermal fluids, from which auriferous minerals were deposited in and around veins
5. the geochemical characteristics of lithologies associated with the mineral deposits

The Ontario Geological Survey is addressing these problems utilizing survey personnel and commencing collaborative research with university and Federal survey geologists.



LEGEND

1. **Consolidated Louanna Gold Mine**
2. **Pancontinental Mining (Canada) Limited**
3. **Magnet Consolidated Gold Mine**
4. **Jellicoe Mine (Dome Mines Limited)**
5. **Brookbank Prospect (Metalore Resources Limited)**
6. **Hard Rock and MacLeod-Cockshutt Mines**
7. **Onaman River Area**

Figure 1 Major exploration and/or development programs in the Beardmore-Geraldton area, 1983.

T.J. Barrett (University of Toronto, Toronto) and Philip W. Fralick (Lakehead University, Thunder Bay, Ontario) are investigating the detailed sedimentology of wackes, siltstones, arkoses, conglomerates, and iron formations in the Beardmore-Geraldton area. Fieldwork was initiated in late 1982 with the objective of defining the sedimentary regimes prevalent during deposition of units in which a considerable portion of the gold mineralization is hosted. The result is being supported by an Ontario Geoscience Research Fund (OGRF) grant.

M.M. Kehlenbeck of Lakehead University commenced a structural analysis of the belt, supported by a Northern Ontario Rural Development Agreement (NORDA) grant to the Mineral Deposits Section. Through rigorous analysis of relationships between cleavage and original sedimentary attitude, it is interpreted that folds in the Jellicoe area (*see* Kehlenbeck, this volume, Figure 1) are upward facing, whereas structure becomes downward facing towards the Geraldton area.

M.J. Lavigne (Mineral Deposits Section) began a 2-year, NORDA-supported research program to assess the relationship between deformation, alteration (metamorphic and hydrothermal), and gold mineralization in the Longlac, Geraldton, and Beardmore areas. Initial results indicate that shear zones spatially associated with past-producing mines may be in excess of 1000 m in width and several kilometres in length. In addition to exhibiting a readily identifiable fabric, the highly deformed zones may also contain a characteristic secondary mineralogy.

A. James Macdonald (Mineral Deposits Section) is continuing the study of the association between gold mineralization and iron formation within the metasedimentary pile. In 1983, the study was expanded to assess the importance of an extensive hydrothermal system developed within both porphyritic phases of the Croll Lake felsic stock (Figure 1, location 6) to the east and the surrounding supracrustals.

The Geological Survey of Canada is supporting 2 M.Sc. theses in the Beardmore-Geraldton belt. Lyn Anglin (Memorial University, St. Johns, Newfoundland) is continuing a study of the relationship between porphyries, iron formation, and gold mineralization. Steven Osterberg (University of Minnesota, Duluth, Minnesota, U.S.A.) commenced a study of base metal sulphide deposits associated with highly altered metavolcanics in the Onaman River area (Figure 1, location 7), northeast of Beardmore.

It is anticipated that the combined efforts of universities and both levels of government in cooperation with the exploration industry will diagnose those features of the geology of the Beardmore-Geraldton belt that are strongly related to gold mineralization. Once established, these relationships may be translated into geological criteria that may be of use to industry in exploration for these types of gold deposits.

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No. 43 A Re-appraisal of the Geraldton Gold Camp

A. James Macdonald[1]

Introduction

In 1982 the Mineral Deposits Section of the Ontario Geological Survey commenced a research program to define the relationships between Archean gold deposits and iron formation sequences (Macdonald 1982, 1983a). This report summarizes the significant observations that can be made based on the 1982 field season and subsequent laboratory research, outlines the rationale for field-based research in the 1983 season, and describes qualitatively the initial results obtained in the Geraldton area. A detailed and quantitative analysis of the data obtained in both 1982 and 1983 will be published in 1984.

Brief Summary of 1982 Research

Detailed geological mapping (1:100 scale) of a glory hole exposed on the Hard Rock Property, less than 100 m south of Highway 11, demonstrated that:

1. gold mineralization is localized within a shallowly plunging (approximately 30° to the west) 'Z'-shaped fold with an amplitude of 50 m
2. mineralization in the iron formation is associated with intense local carbonatization of originally pelitic interbeds, a hydrothermal alteration that is not prominent outside the Z-shaped fold
3. stratiform auriferous pyrite, pyrrhotite, and arsenopyrite are locally present within oxide-bearing banded iron formation; sulphide minerals are replacement selvages associated with cross-cutting auriferous quartz-carbonate-tourmaline-sulphide veins and result from sulphidation of the original stratiform oxides
4. a regional cleavage, prominently developed in wackes in the Geraldton area, is folded about the hinges of small Z-shaped folds (amplitudes of less than 1 m), indicating that the latter structures are younger than the period of regional deformation, as opposed to being soft-sediment slump features
5. auriferous, quartz-carbonate-tourmaline veins cut—and are consequently younger than—the small Z-shaped folds that, like the larger structure, plunge at approximately 30° to the west
6. from 4 and 5 above, field evidence suggests that at least a portion of the gold mineralizing event postdates 2 discrete phases of deformation

Objectives of the 1983 Field Season

As yet, no evidence has been found of a synsedimentary component of gold concentration. Preliminary analysis of mesobands within the iron formation from the Geraldton area gives values generally less than 100 parts per billion (ppb), if replacement sulphide minerals are not present (J.M. Franklin, Geologist, Geological Survey of Canada, personal communication, February, 1983). Field evidence as outlined above indicates an external source for the mineralization, as first suggested by Pye (1952) and Horwood and Pye (1955).

Two principal theories may be proposed for epigenetic gold mineralization in the Archean: a) metamorphic devolatilization; and b) magmatic hydrothermal venting. Pye (1952) suggested that the shape of the Croll Lake Stock, when taken in conjunction with the shallow regional plunge of most geological contacts in the Geraldton area, may indicate that a thin (less than 1 km wide) proboscis of granitic material may protrude beneath the markedly linear package of supracrustals within which the bulk of the deposits are found. The favourable sequence within the supracrustals is characterized by a wide variety of lithologies (metasediments ranging from pelites to arkoses to polymict conglomerates, porphyritic felsic intrusions, massive mafic flows or intrusions, metabasalts, and iron formations), and a complex deformational history dominated by isoclinal folding (Ferguson 1967) and intense shearing (e.g. the Bankfield-Tombill and Portage-Longlac shear zones; *see* Pye 1952; Horwood and Pye 1955; Lavigne this volume). For discussion, this lithotectonic package, which is unique in the Geraldton area, may be informally termed the "Barton Bay" zone, named after the prominent east-trending bay that branches off Kenogamisis Lake to the south and west of Geraldton.

The principal objective of the 1983 field season was to determine the full distribution of veining and mineralization, and to examine this field evidence in the context of the metamorphic devolatilization or magmatic hydrothermal venting models.

Clastic metasediments in and around the open stope on the Hard Rock Property exhibit a prominent pressure solution fabric that trends approximately east. Where original sedimentary bedding is preserved in minor fold structures, the pressure solution fabric is axial planar and transects bedding. The metawackes and siltstones exhibiting this feature also contain variably deformed carbonate veins and ptygmatically folded, quartz-carbonate veins (the "wiggly" veins, as described by Horwood and Pye 1955). It has been suggested (P.J. MacGeehan, Geologist, Westin Mining Corporation, Australia, personal communication, 1983) that these features may reflect a lengthy history of intimately associated deformation and pressure solution. The hypothesis is being tested by a combination of: a) field mapping to assess the magnitude of the zone that has suffered pressure solution; and b) laboratory analysis to determine whether individual components may be chemically traced from sedimentary rocks into veins.

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If on the other hand the Croll Lake granite Stock, is in some way related to mineralization, evidence of a large scale hydrothermal system should be present within the intrusion. This hypothesis was tested in 1983 by geological mapping along traverses through the centre of the stock in Croll Township, along Highway 11 where road cuts expose part of the northern quarter of the intrusion and around Mineral Lake, and lastly at the western "nose" where granite is in contact with 'greenstone' supracrustals, approximately 1.5 km from the Roche Long Lac Gold Deposit. A 100 m grid (surveyed by chain and compass) was placed over the western contact of the stock, covering an area of approximately 2.5 km^2, and was used as the basis for production of a 1:2000 scale geological map. Preliminary observations from the detailed mapping are described below.

Field Observations in the Croll Lake Stock and Environs

The Croll Lake Stock

The Croll Lake Stock is a zoned felsic intrusion that is relatively undeformed, although weakly foliated near contacts within the supracrustals. The core (and bulk) of the intrusion is granitic *sensu stricto* (note: all lithological identifications require thin section confirmation), surrounded successively by rinds of quartz monzonite, diorite, plagioclase-phyric diorite, and quartz porphyry. The outcrop widths of these peripheral units, particularly those that are porphyritic, are greatest in the "nose" region of the stock near Mineral Lake. Several approximately east-trending, porphyritic dikes extend into the 'greenstones'. Both quartz and feldspar porphyry dikes have been mapped.

Supracrustals

Only metamorphosed mafic igneous rocks are exposed in contact with western margins of the Croll Lake Stock. The bulk of these rocks are pillow lavas and associated massive flows and breccias. Other coarser grained (up to 2 mm) mafic units may be intrusions or thick flows. Limited outcrop precludes conclusive interpretation of the origin of the coarser grained mafic units, although intrusive contacts were not observed.

Within approximately 100 m of the contact with the Croll Lake Stock, the metavolcanics are hornfelsed (silicified and impregnated with fine-grained pyrite and locally pyrrhotite), particularly well displayed in supracrustal roof pendants within the granitic body.

In many outcrops at the western end of the "nose", curious quartz, quartz-feldspar, or quartz-feldspar-tourmaline ovoids up to 2 cm in length may be found within the mafic rocks. At first sight, the ovoids appear to be similar to amygdules. Their marked spatial association with porphyritic dikes, their occurrence throughout pillows (as opposed to being zoned about the pillow centres), and the local occurrence of tourmaline within the ovoids suggests a more complex origin. This feature cross-cuts pillow selvages and is interpreted to be a form of incipient metasomatic alteration of the mafic rock. The ovoids have been mapped in outcrops westward from the granite "nose" to the Roche Long Lac Deposit. Secondary amphibole is also locally well developed in both massive and pillowed flows. It also cuts across pillowed margins and is clearly related to a process that postdates basalt extrusion. The presence of secondary amphibole in the Geraldton area is being addressed by Lavigne (this volume).

Mineralization

Vein type mineralization in the Croll Lake Stock is present throughout the intrusion, although vein density is lowest in the north, intermediate in the south, and highest to the west in the "nose". Veins of quartz-K-feldspar ± chlorite ± tourmaline ± sulphide minerals (pyrite, chalcopyrite, galena) are typically 1 to 5 cm wide in the centre of the stock with a vein density of 2 to 4 per metre being common. Locally, veins may reach up to 1 m in width. Wallrock selvage silicification for up to 10 cm on either side of a vein is characteristic.

In the nose of the stock an extensive hydrothermal vein system is present, associated principally with the marginal porphyritic phases of the granite and found also in the adjacent mafic supracrustals. Vein density may reach in excess of 10 veins (average width of 1 cm) per metre, somewhat reminiscent of porphyry-type deposits in the Cordillera of Central and North America. Vein widths may reach in excess of 2 m, over exposed strike lengths of 20 m. Further stripping with heavy machinery is required to determine strike continuity. Quartz and tourmaline are the dominant minerals filling the veins. Locally an iron-bearing carbonate is prominent and sulphide minerals are ubiquitous, although in low concentrations (usually less than 2%, commonly 0.5%). The sulphide assemblage includes pyrite, pyrrhotite, chalcopyrite, and molybdenite. The zone containing molybdenite (with quartz, tourmaline, and locally epidote) is in excess of 1.5 km in diameter and is found both within the porphyritic margin of the stock and up to 1 km to the west of the contact, within the mafic metavolcanics.

Some 24 small trenches are present in the contact area at the "nose" of the granite. Data from the work performed on rocks sampled from the trenches are not available. According to Fairbairn (1938), Mat-a-Lac Gold Mines (1936) Limited reported galena and pyrite in small amounts. They did not report important gold values.

Planned Research to Augment the 1983 Field Season

Several hundred samples of vein mineralization and wall-rock have been collected from the Croll Lake Stock and the supracrustal units with which it is in contact. The bulk of these samples are from the Mineral Lake area. Prior to detailed petrography, and a multi-element analysis of these rocks, which can take several months, selected samples will be analyzed for their gold content. Rapid release of these data will be of most immediate use to land owners in the Geraldton area and to resource corporations wishing to explore there.

Subsequent detailed research in the Mineral Lake-Geraldton area is designed to provide insight into the origin of the gold-bearing hydrothermal solutions that deposited mineralization in the Hard Rock and MacLeod-Cockshutt Deposits, and the genetic processes that resulted in the concentration of approximately 4 million ounces of gold into mineable units. The research will test 2 hypotheses, which will be supported or refuted by the results of data obtained within the laboratory, namely:

1. that the hydrothermal fluids were derived by venting from the Croll Lake granite Stock as it crystallized
2. that the hydrothermal fluid underwent physical change (pressure and/or temperature) that resulted in CO_2 effervescence of the hydrothermal fluid (i.e. release of CO_2) coincident with gold mineralization

Preliminary studies in May 1982 (Macdonald 1983b) of primary fluid inclusions within the proposed hydrothermal system between Mineral Lake and the Geraldton area indicate a complex fluid history, involving multicomponent fluids and evidence of component separation. Secondary fluid inclusions are more saline (cubes of NaCl are present within inclusions). It will be necessary, although difficult, to determine exactly where gold deposition takes place within the highly complex fluid history in the Geraldton area. Detailed petrography and microthermometry will be utilized to determine whether one or both of the hypotheses has any merit.

If the first hypothesis can be proven, it will then be necessary to determine what process or processes within the granite gave rise to the mineralizing event and whether there is any intrinsic characteristic of the granite that may be useful as an exploration tool in other areas.

If the second hypothesis is shown to be tenable, then it may be possible to utilize a new approach to exploration for Archean lode gold deposits. The study of fluid inclusions, trapped in minerals during the ore-forming process, is a relatively inexpensive technique requiring low initial capital cost. It may be possible to use simple microthermometric observation of fluid inclusions in, for example, vein quartz, to determine whether certain components, such as CO_2, are present and whether they exhibit characteristics, such as evidence of phase separation, typical of other lode gold deposits.

Summary

One of the more significant results of the 2 years' field work in the Geraldton Camp has been the inability to detect a synsedimentary source of gold. All evidence, to date, suggests an epigenetic introduction of gold and associated hydrothermal minerals into the Barton Bay lithotectonic zone. If further research continues to support this scenario for ore formation in the Geraldton area, it is hoped that a set of field-oriented criteria can be established to provide geological guides for use in exploration.

Acknowledgments

I would like to thank J.L. Oliver, of the Minex M.Sc. program at Queen's University, for his high standard of assistance to this program. Without Jim's personal abilities and his willingness to extend his efforts beyond expectation, the results of this year's field work could not have approached the current status. Lac Minerals Limited of Toronto is to be thanked for continuing to permit Ontario Geological Survey personnel access to their extensive properties in the Geraldton area. Staff of the Geraldton Regional Fire Centre provided us with constant logistical support, good humour, accommodation, and first class sustenance. We thank the staff of the North Central Region of the Ontario Ministry of Natural Resources for their tolerance. The field program has benefited much from informative discussion with geologists from industry and both Federal and Provincial Geological Surveys.

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No. S44 Gold Deposits of the Geraldton Area

M.J. Lavigne, Jr.[1]

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Introduction

The geology of the Beardmore-Geraldton district, specifically those areas in the vicinity of past-producing gold mines, is being re-evaluated in order to better define the environment in which these gold deposits formed. Studies to date covering portions of the Geraldton area are briefly described in this report. Horwood and Pye (1955), Pye (1952), and Bruce (1937) have described the geology and gold deposits in the vicinity of Geraldton. It is the intention of this study to outline and describe those geologically anomalous rocks which occur near the deposits in order to either reaffirm or reinterpret their origins and their link to the gold mineralization. The geology in the vicinity of the Geraldton Camp will be compared to areas devoid of gold mineralization.

Lithological Association of Geraldton Gold Deposits

As emphasised by Horwood and Pye (1955), intense deformation is the most ubiquitous feature of these gold deposits; they are spatially associated with a major fault zone, the Bankfield-Tombill fault, and much of the mineralization is found in sheared and highly folded rock. However, several other features of the Geraldton geology stand out:

1. There is an anomalous percentage of mafic intrusive rocks within both the mafic volcanic and sedimentary domains. Especially notable are the lensoidal intrusions found within the Bankfield-Tombill fault zone.
2. All major prospects and past producers excluding the Little Long Lac and the McLellan contain porphyritic felsic dikes, many of which appear to have had an influence in localizing mineralization.
3. There is a distinct regional spatial association of gold deposits and iron formation. Examination of aeromagnetic data (ODM-GSC 1974) reveals an anomalously high concentration of iron formation which coincides with the gold deposits. This anomaly decreases to the west, as does gold production (Pye 1952, Figure 7).
4. Unlike other Archean gold mining camps, carbonate alteration is not widespread, and strong carbonate alteration is restricted to the ore zones. Mafic volcanic rocks in Croll Township and eastern Ashmore Township have undergone potassic, silicic, and chloritic alteration. The proximity of this alteration to the Croll Lake batholith suggests that the intrusion may have been the cause of alteration.

Bankfield-Tombill Fault

As part of this study, the Bankfield-Tombill fault zone was traced from the western boundary of Errington Township to the southern boundary of Ashmore Township on Kenogamisis Lake, a distance of 16 km; within this interval the fault zone is very well exposed, permitting a detailed examination, but its possible westerly extension is overburden covered. In addition, the full width of the zone affected by deformation associated with this fault was delineated; widths mapped vary from 1000 to 3000 m.

As previously mentioned, mafic intrusive rocks and felsic porphyritic dikes are found along the entire length of the Bankfield-Tombill fault (Figure 1). Cross-cutting relationships were established on the Bankfield Mine Property. Both the felsic porphyritic dikes and gabbroic intrusions cross-cut banded iron formation and wackes. These relationships were also established by Horwood and Pye (1955) at many other mine sites. Contact relationships between the mafic intrusion and wallrock cannot be established along much of the fault length as the intrusion has undergone severe deformation, producing a carbonate-chlorite-albite schist and breccia. This brecciated unit was previously interpreted as a volcanic breccia by Pye and Horwood (1955). The breccia achieves a width of 300 m at the Mosher, MacLeod, and Hard Rock Mines.

Progressive deformation of the intrusion can be consistently demonstrated at several locations. Deformation intensity progresses from the undeformed, unfoliated, medium-grained gabbro to a zone with preferred orientation of the mafic minerals and abundant anastomosing, chloritized, 1 cm, shears in which the mafic clots are elongate. This zone is succeeded by the development of a weak penetrative foliation, strong mineral alignment, and some grain size reduction. Zones with strong penetrative foliation, defined by well developed mineral segregations, have undergone nearly complete grain reduction as the rock is now fine grained to aphanitic. Complete deformation is marked by the development of shear bands which cross-cut foliation at 30°. Dextral movement along these shear bands produced the breccia by counter-clockwise rotation of the foliated fragments.

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Felsic porphyritic dikes within the breccia zones have not undergone the same intensity of deformation, but are nonetheless foliated. On the Bankfield Mine Property, a porphyry dike cross-cuts the foliation in the enclosing mafic breccia and contains xenoliths of the breccia. This implies a prolonged history of fault movement and intrusive activity. The fault served as a locus for mafic intrusions which were subsequently deformed, followed by the intrusion of felsic porphyritic dikes. Many of these porphyries have been altered and mineralized, such as the F-zone at the Mosher Mine. This implies that at least a portion of the mineralization was a late event in the tectonic evolution of the Geraldton belt.

Houck, Oakes, and Daley Townships

Houck, Oakes, and Daley Townships were examined in a reconnaissance fashion for 2 reasons:

1. to examine the effect of the Croll Lake batholith on mafic volcanic rocks in an area apparently devoid of gold mineralization, and to compare these rocks to the altered mafic volcanic rocks west of the batholith, in the vicinity of past-producing gold mines
2. to examine a portion of the Geraldton belt which has only a few gold showings and compare its geology to mineralized areas such as Geraldton

Alteration in these townships may be attributed to several causes:

1. Faulting and high grade metamorphism have occur-

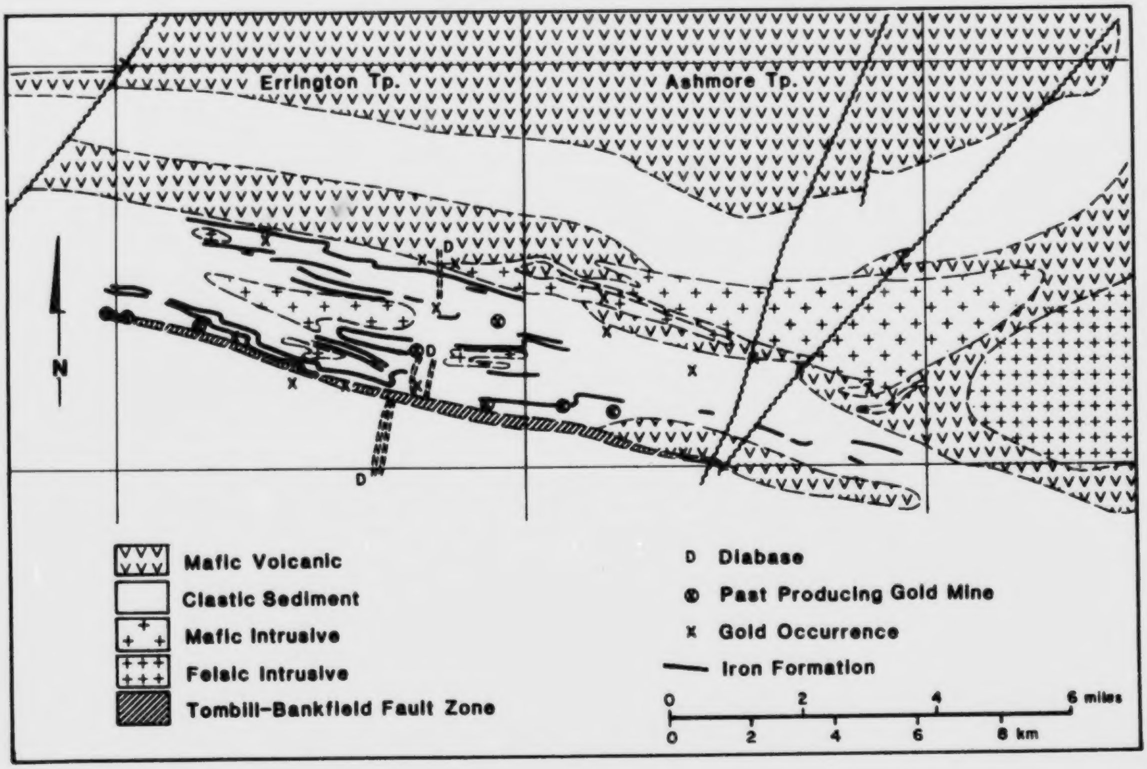
Errington Tp.
Ashmore Tp.
N
D
Mafic Volcanic
Clastic Sediment
Mafic Intrusive
Felsic Intrusive
Tombill-Bankfield Fault Zone
D Diabase
Past Producing Gold Mine
x Gold Occurrence
Iron Formation
0 2 4 6 miles
0 2 4 6 8 km

Figure 1. General geology of the Beardmore area.

red along basement-"greenstone" contacts producing epidote-enriched, strongly foliated to migmatitic rocks.

2. Zones of intense deformation adjacent to the Kenogamisis River may be attributed to faulting and abundant magmatic activity, as both mafic intrusions and felsic porphyritic dikes are present.
3. Carbonate alteration is common in this northeast-trending zone; both the wackes and mafic volcanic rocks at the contact with the Croll Lake batholith have been metamorphosed and metasomatized. The wackes are silicified, while the mafic volcanic rocks have been recrystallized possibly at amphibolite facies. Sulfurization is also common along this contact.
4. Based on field observations, the average metamorphic grade of the supracrustals between the Croll Lake batholith and basement to the north is higher than in Geraldton to the west.

Conclusion

The tectonic events responsible for the deformation of the rocks in the vicinity of the gold mines in Geraldton were associated with a zone of major crustal weakness, the Bankfield-Tombill fault, which served as a conduit for mafic and felsic magmas and volatiles which were responsible for the generation of the gold deposits. The presence of the porphyries, mafic intrusions, metasomatism, deformation, and the juxtaposition of major lithologic blocks can be used as a guide to major crustal sutures and possibly gold mineralization.

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No. S45 Structural Studies in the Beardmore-Geraldton Area

Manfred M. Kehlenbeck[1]

THIS PROJECT WAS FUNDED EQUALLY BY THE GOVERNMENTS OF CANADA AND ONTARIO UNDER THE NORTHERN ONTARIO RURAL DEVELOPENT AGREEMENT (NORDA).

Introduction

The objective of this project is to provide data on the structural geometry of the rocks in the Beardmore-Geraldton region, and to describe the relationship between the rocks of the Wabigoon and Quetico Subprovinces in this area.

During the 1983 field season, structural mapping was initiated within a relatively narrow corridor paralleling Highway 11 from a point about 10 km south of Beardmore in the west to Longlac in the east. Numerous secondary roads provide access to areas north and south of Highway 11. To permit maximum coverage of the area, no traversing or detailed mapping was undertaken. This summary presents the results obtained during the preliminary stage of this structural study.

Structural Elements and Structure

During the preliminary survey, field observations were primarily confined to a succession of metasediments exposed in an east-trending belt between Beardmore and Geraldton. This turbiditic succession includes slates, fine-grained siltstones, wackes, and sandstones, as well as conglomeratic layers. The metasedimentary sequence as a whole has been designated as the southern metasedimentary belt (Mackasey 1976) to distinguish it from similar rocks exposed in 2 subparallel belts to the north. These metasedimentary belts are separated from each other by massive and pillowed mafic metavolcanics.

Orientations of bedding planes (S_0) were readily obtained from exposures of the well stratified sequence of wackes and slates. In these rocks, grain size gradation or cross lamination make it possible to determine the local younging direction in most outcrops. In areas underlain by metavolcanics, pillowed flows are relatively abundant throughout. In most exposures studied, the individual pillows are too deformed to permit determination of local younging directions or primary depositional surfaces (Borradaile 1982b).

In nearly all outcrops, a well developed cleavage (S_1) is visible. Careful observations in the field and data from several thin sections of representative samples showed that the rocks possess only 1 cleavage and that this cleavage is coplanar, or nearly so, with the axial surface of folds. In several outcrops of single folds, it is possible to demonstrate that the bedding-cleavage intersection lineations measured on opposite limbs of the same fold are essentially coaxial, suggesting that the folds are plane cylindrical (Turner and Weiss 1963, p.108). It also follows from these observations that the S_1 cleavage accompanied the dominant fold episode, and, since no transected folds were found, 1 major folding appears, at present, to have occurred in this area.

Since the cleavage is axial planar to a set of folds, bedding-cleavage relationships may be applied to map out mesoscopic folds, and bedding-cleavage intersection lineations (S_0/S_1) are coaxial with the axes of these mesoscopic folds (Figure 1).

Fold axis orientations vary in trend and plunge. Near Beardmore and east toward Jellicoe, fold axes and S_0/S_1 intersection lineations plunge east at moderate angles. East of Jellicoe, the plunge steepens and the folds have vertical plunges. Here, they are neither synforms nor antiforms, but rather are sideways closing folds. From this point eastward towards Geraldton, folds plunge westward (Figure 1). Variations in plunge and trend reflect the strongly curvilinear hinge lines of the folds.

As Figure 1 shows, the structural facing of the folds (Shackleton 1958; Borradaile 1976) near Beardmore is upward and to the east. The structural facing direction remains eastward from Beardmore to Geraldton; however, upward facing folds near Beardmore become sideways facing east of Jellicoe and downward facing at Geraldton. Poulsen *et al.* (1980) have reported on an inverted Archean succession at Rainy Lake, Ontario. Since the structural facing reflects the direction in which the stratigraphy as a whole is getting younger, the structural data recorded in the field suggest that synclines and anticlines west of Jellicoe gradually progress to sideways closing folds, and then become antiformal synclines and synformal anticlines near Geraldton (Figure 1). Similar structures have been reported (Borradaile 1982a) in a metasedimentary succession from the Quetico Subprovince near Calm Lake, Ontario.

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Shear discontinuities parallel to axial surfaces are common in folds near Geraldton. Some individual folds show evidence of substantial transposition of the layers and these folds could be referred to as shear folds (Ramsay 1967, p.423). West of Geraldton, obvious shear discontinuities become less prevalant and are rare in mesoscopic folds near Jellicoe and westward. Based on the available data, it is premature to speculate on the regional extent of transposed bedding planes.

In several outcrops, a late crenulation cleavage is present. This subvertical cleavage strikes north-south and is coplanar with axial surfaces of minor chevron folds developed in S_1 cleavage planes. In a few outcrops, measured intersection lineations between S_1 and the crenulation cleavage plunge steeply northward. At present, the regional extent of this crenulation cleavage is not fully known, but it appears to become more dominant in rocks exposed to the north. Similarly, large chevron folds with

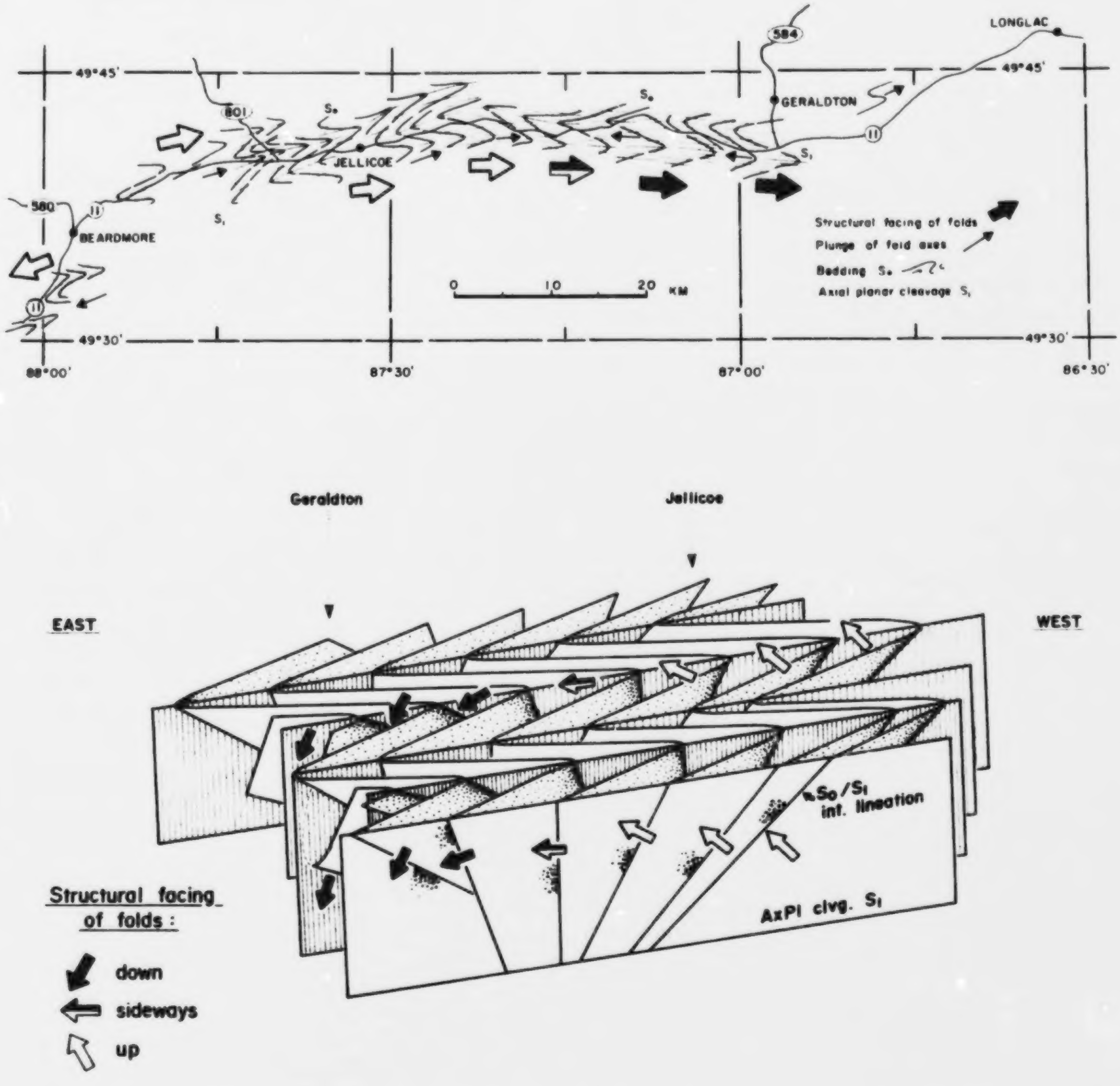
LONGLAC
584
49°45'
49°45'
801
S_0
S_0
GERALDTON
JELLICOE
11
S_1
580
11
BEARDMORE
S_1
Structural facing of folds
Plunge of fold axes
Bedding S_0
Axial planar cleavage S_1
0
10
20 KM
11
49°30'
49°30'
88°00'
87°30'
87°00'
86°30'
Geraldton
Jellicoe
EAST
WEST
S_0/S_1 int. lineation
AxPl clvg. S_1
Structural facing of folds :
down
sideways
up

Figure 1. Simplified structural geology of the Beardmore-Geraldton area illustrating changes in attitudes of folds.

north-south striking axial surfaces occur in metasediments and metavolcanics in the northern part of the area.

Several north-south road traverses were undertaken to obtain some data on the relationship between the metasedimentary and metavolcanic strata, and the rocks exposed to the south which form the migmatitic and gneissic terrain typical of the Quetico Subprovince.

In all cases, the data are inconclusive at present and do not permit a definitive description of the 'boundary' between the Wabigoon and Quetico Subprovinces.

Structurally, the metasediments have dominant east-trending linear structures which persist southward into the gneisses and migmatites. Primary bedding surfaces, which are the dominant S surfaces in the metasediments, gradually become subordinant to a strongly developed schistosity and gneissosity. No significant change in attitudes of linear or planar structures appears to occur and no evidence of major shear zones or faults has been found.

Conclusions

Preliminary field observations indicate that the metasedimentary and metavolcanic strata have been folded during a single folding episode into a series of synforms and antiforms. The folds have strongly curvilinear hinge lines and a subvertical east-west striking axial planar cleavage. Structural facing is consistently eastward but varies from upward facing in synclines and anticlines in the western part of the area, through sideways facing folds to downward facing antiformal synclines and synformal anticlines near Geraldton.

Shear discontinuities parallel to the axial surfaces of folds suggest that the folds are likely to have formed in response to a progressive inhomogeneous simple shear together with a uniform homogeneous strain.

The structural relationship of the stratified metasediments and interlayered metavolcanics to the migmatites and granitic gneisses exposed to the south is not a distinctive one. Based on the data, planar and linear structural elements appear to persist throughout without significant changes in attitude. No evidence for major shear zones or faults has been found. The 'boundary' between the Wabigoon and Quetico Subprovinces in this area may be represented by a rather wide zone in which shear folding and transposition of primary layering have occurred, involving considerable volumes of rock of both subprovinces.

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No. S46 The Sedimentology of Banded Iron Formation in the Beardmore-Geraldton Greenstone Belt: A Preliminary Appraisal

Philip W. Fralick[1] and T.J. Barrett[2]

THIS PROJECT WAS FUNDED BY A GRANT FROM THE ONTARIO GEOSCIENCE RESEARCH FUND (OGRF).

Introduction

Oxide facies banded iron formation (B.I.F.) interlayered with clastic rocks has been reported from several areas in the Canadian Shield of Ontario (Teal and Walker 1977; Wood 1980; Meyn and Palonen 1980; Hyde 1980). The clastics usually consist of fine-grained wackes of variable thickness, which are intimately interlayered with thin, laterally extensive magnetite laminae. Little is known of the depositional environment of such successions. The present project was initiated to expand our understanding of how magnetite-wacke associations form, by means of a detailed stratigraphic and sedimentological examination of such rocks that crop out in the Beardmore-Geraldton greenstone belt.

Hopefully, the results of the study will not only be of interest from an academic viewpoint but also have practical value. Occurrences and economic deposits of gold are commonly associated with B.I.F. in the Beardmore-Geraldton area. Ductility contrasts between the B.I.F. and surrounding, more competent, clastics may have caused the formation of gashes or shears which later acted as a control on the development of gold-bearing vein systems (Macdonald 1983). Thus, it is also of importance to develop a model which can predict likely areas where thick B.I.F. and competent clastics will be spatially associated.

General Geology

The Beardmore-Geraldton "greenstone belt" is an east-trending erosional remnant of a volcanic-sedimentary basin surrounded by a granitic and gneissic terrain. Sections studied occur in an 80 km long portion of the belt between Lake Nipigon and Kenogamisis Lake (*see* Location Map, Mason and Macdonald, this volume). The exposed rock succession in the basin is composed of approximately equal amounts of volcanic rocks and sedimentary rocks. Large east-trending volcanic terrains separate the sedimentary pile into 2 to 3 belts. Polymictic, cobble and pebble conglomerates are more common in the northern belt and generally decrease in proportion southward, so that wacke-argillite successions form most of the southern clastic belt. Most of the outcrops we have examined are in the southern belt. Banded iron formation occurs sporadically interbedded with wackes in all areas of the Beardmore-Geraldton "greenstone belt", but is far more prevalent in the southern belt, particularly in the region near Geraldton.

Sedimentology

Approximately 20 outcrops of B.I.F. were studied in detail. From this, 2 general lithofacies successions can be constructed: one, magnetite dominated; the other, clastic dominated. These 2 successions form end members in a continuum of outcrop types.

The magnetite-rich end member (an example is present on the island in Barton Bay, Kenogamisis Lake) consists of an alternating series of magnetite-rich and magnetite-poor zones, the former generally on the order of 0.5 to 2 m in thickness. The magnetite-rich zones are composed of very thinly and parallel-laminated magnetite with occasional centimetre thick siltstone layers. As the clastic-rich portions of the succession are approached, the proportion of thin siltstone beds increases until they dominate the rock. Siltstones and fine-grained sandstones interlayered with occasional bundles of magnetite laminae form the clastic-dominated zones in the outcrop. The clastic units may reach 20 cm in thickness and usually contain abundant parallel lamination. Grading is sometimes visible but tops are difficult to define, possibly the result of winnowing of the upper portions of beds by bottom currents.

The clastic-dominated end member is typified by a section present in the northeastern portion of the study area near Hutchison Lake. This succession also fluctuates between clastic-rich and clastic-poor zones, but the overall proportion of magnetite in the section is much lower than

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on the island in Barton Bay. Medium-grained, clay-rich, thin sandstone beds are interbedded with parallel-laminated magnetite horizons (generally <1 cm thick) over intervals of up to 30 cm thickness. The sandstone beds, which in these intervals are greenish, are usually 1 to 3 cm thick, parallel laminated, and show well developed grading at their base and top with a nongraded central portion. Occasionally, bed tops composed of clay-rich sandstone grade quite smoothly through a few millimetres into a magnetite-rich band. Study of thin sections has confirmed that at least some of the magnetite laminae were deposited together with fine-grained tops of underlying sandstone beds.

The intervals containing magnetite at the Hutchison Lake exposure are separated by magnetite-free intervals up to 50 cm thick, which are dominated by medium- and coarse-grained, clay-poor, whitish sandstones. The sandstone beds average 1 to 3 cm thick, though some may reach 30 cm in thickness. The sandstones are poorly sorted, with coarse sand grains floating in a matrix of medium- and fine-grained sand. They frequently grade upward into a siltstone top. Millimetre thick magnetite laminations are rarely found interbedded between medium- and coarse-grained sandstones.

All gradations between these 2 end members have been observed. Particularly good examples of intermediate types of successions are present at the Leitch Mine, Soloman's Pillars, and Spawn Lake. Most areas mapped exhibit crude coarsening upward cycles of one to several metres thickness. Generally, magnetite-rich and fine-grained, clastic-rich intervals display a progressively greater proportion of clastic material upward until a sandstone-dominated succession develops. In contrast with this, the upward transition from clastic-rich to clastic-poor portions of the section tends to be more abrupt. Commonly, a succession of coarsening upward cycles occurs, stacked one on top of another.

Two B.I.F.-bearing successions contain quite different lithologies from those described above. On the southern shore of Barton Bay, intervals of laminated B.I.F. up to 15 cm thick are sandwiched between coarse- to very coarse grained sandstone beds up to 3 m thick. Grading in the sandstones is usually present only near their tops, where the grain size may decrease to fine-grained sand. A few beds contain abundant intraformational rip-up clasts composed of siltstone/magnetite.

The second unusual outcrop occurs in the central portion of the study area near the eastern shore of Watson Lake. Here, 2 thin conglomerate beds (30 to 50 cm thick) occur within a typical thinly bedded wacke succession containing magnetite laminations. This outcrop was previously noted by Mackasey (1975, p.17-18).

Discussion

Some of the clastic beds associated with occurrences of B.I.F. contain sedimentary structures and grading typical of fine-grained turbidites (Hesse and Chough 1980; Stow and Shanmugam 1980). However, this does not necessitate deposition in a deep-water environment. Thinly bedded turbiditic deposits are quite common in prodelta areas of the modern Mississippi Delta (Coleman and Prior 1982) and coarser grained, storm-produced turbidites have been described from the continental shelf by Hamblin and Walker (1979). The observation that a considerable proportion of the B.I.F. and thinly bedded clastics occurs stratigraphically proximal to fluvial sandstones and conglomerates (for fluvial interpretation *see* Devaney 1983) indicates that the water depth in which chemical sediments formed may not have been very great. However, a major stratigraphic hiatus separating the subaerial and marine sediments cannot be ruled out. Thus, we have indications that the B.I.F. formed in relatively shallow depths, but a deep water origin remains possible.

The coarsening upward B.I.F.-clastic cycles were probably caused by the progradation of clastic-sediment lobes. At times when little detritus was being supplied, magnetite-rich units developed. As the clastic input increased, the succession slowly changed from chemical dominated to clastic dominated. Some of the chemical sediment present was reworked by and incorporated into turbidity flows. Thus, magnetite-rich tops were formed on the occasional clastic bed. Proximal to the sediment source, the cycles became totally clastic as individual medium-grained sand lobes built outward (e.g. traversing southward through the Leitch Mine trench). In more source-distal areas, magnetite-rich intervals are interbedded with medium-grained clastics (e.g. Hutchison Lake).

The 2 sections containing magnetite interbedded with coarse-grained clastics or conglomerates (Barton Bay and Watson Lake, respectively) may represent areas where magnetite was episodically deposited in a very shore-proximal environment. The thick-bedded, very coarse grained sandstones present on the shore at Barton Bay represent fluidized-flow deposits, some of which contain abundant rafted, intraformational clasts. It is doubtful that the clay-poor nature of these sandstones could have been maintained after prolonged flow over a muddy (magnetite-clay-rich) bottom, as mud from the substrate would tend to become incorporated in the flow. These fluidized-flow deposits thus seem to represent slump events originating off fluvial feed points. Deposition into the adjacent marine portion of the basin would produce stratigraphic successions containing pronounced ductility contrasts. The thick coarse-grained sandstone (or conglomerate) beds should eventually form rigid layers separating more ductile magnetite horizons. During periods of stress, the magnetite should fold plastically while the sandstones should deform brittly and develop a fracture pattern. Such fractures might be filled by veins at a later date. Accordingly, areas where B.I.F. was deposited proximally to the shoreline (as inferred from fluidized coarse-grained sand flows and conglomerate) might be potentially favourable for the later development of vein systems.

Future Work

This paper is based on a preliminary examination of our data. Future work will entail an in-depth study of the sections to further determine their stratigraphic similarities and differences. From this we hope to:

1. construct depositional models which will interrelate the various clastic lithologies
2. provide a paleoenvironmental setting which will satisfy the observed field relations between the clastic lithologies and the B.I.F.

A final aim is to isolate possible areas where lithological, and therefore ductility, contrasts within the sediment sequence will be the highest.

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Gold Studies in the Red Lake Area

Introduction by A.J. Andrews[1] and Marcel E. Durocher[2]

This district scale, multidisciplinary study was initiated in 1982, in conjunction with ongoing Ontario Geological Survey projects in the Red Lake area involved with regional lithological mapping, stratigraphic studies, and aspects of mineral deposits geology (Pirie 1981; Wallace 1982; Durocher and van Haaften 1982).

The object of this study is to develop an understanding of the nature and timing of gold mineralization within the context of the stratigraphic, structural, metamorphic, and alteration history of a "greenstone belt" (Andrews 1982), and thereby develop a set of refined geological observations which will form the basis of useful exploration criteria for gold mineralization in Archean volcanic environments (Colvine 1983).

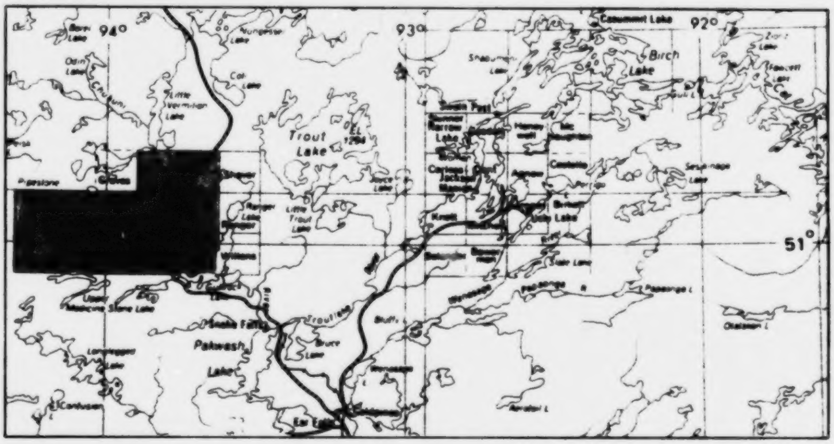
During the 1983 field season, the base program (as described by Andrews 1982) continued and was expanded to include a number of additional Ontario Geological Survey (OGS) and Ontario Geoscience Research Fund (OGRF) supported components as described below. The main focus of the 1983 field work involved:

1. continued study of metamorphic, alteration, and structural features, their history, and relationship to gold mineralization
2. detailed structural analysis of selected key areas
3. U-Pb zircon geochronology of selected gold deposits
4. fluid inclusion and stable isotopic reconnaissance of selected gold-bearing quartz veins

These studies (Figure 1) were conducted in 3 main parts of the belt, referred to as the Eastern Section (Dome, Balmer, Bateman, and McDonough Townships), the Flat Lake-Howey Bay Deformation Zone (Baird and Heyson Townships), and the Pipestone Bay-St. Paul Bay Deformation Zone (Ball, Todd, and Fairlie Townships). The following brief outline presents the various components of this year's work within the context of the overall project. Details concerning each component study are described in the individual reports which follow.

Alteration and Metamorphism

Studies concerning alteration, metamorphism, and regional aspects of structure are being conducted by A.J. Andrews (Eastern Section), M.E. Durocher and H. Hugon (Flat Lake-Howey Bay Deformation Zone), and M.E. Durocher and P. Burchell (Pipestone Bay-St. Paul Bay De-



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

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[2] Resident Geologist, Ontario Ministry of Natural Resources, Red Lake

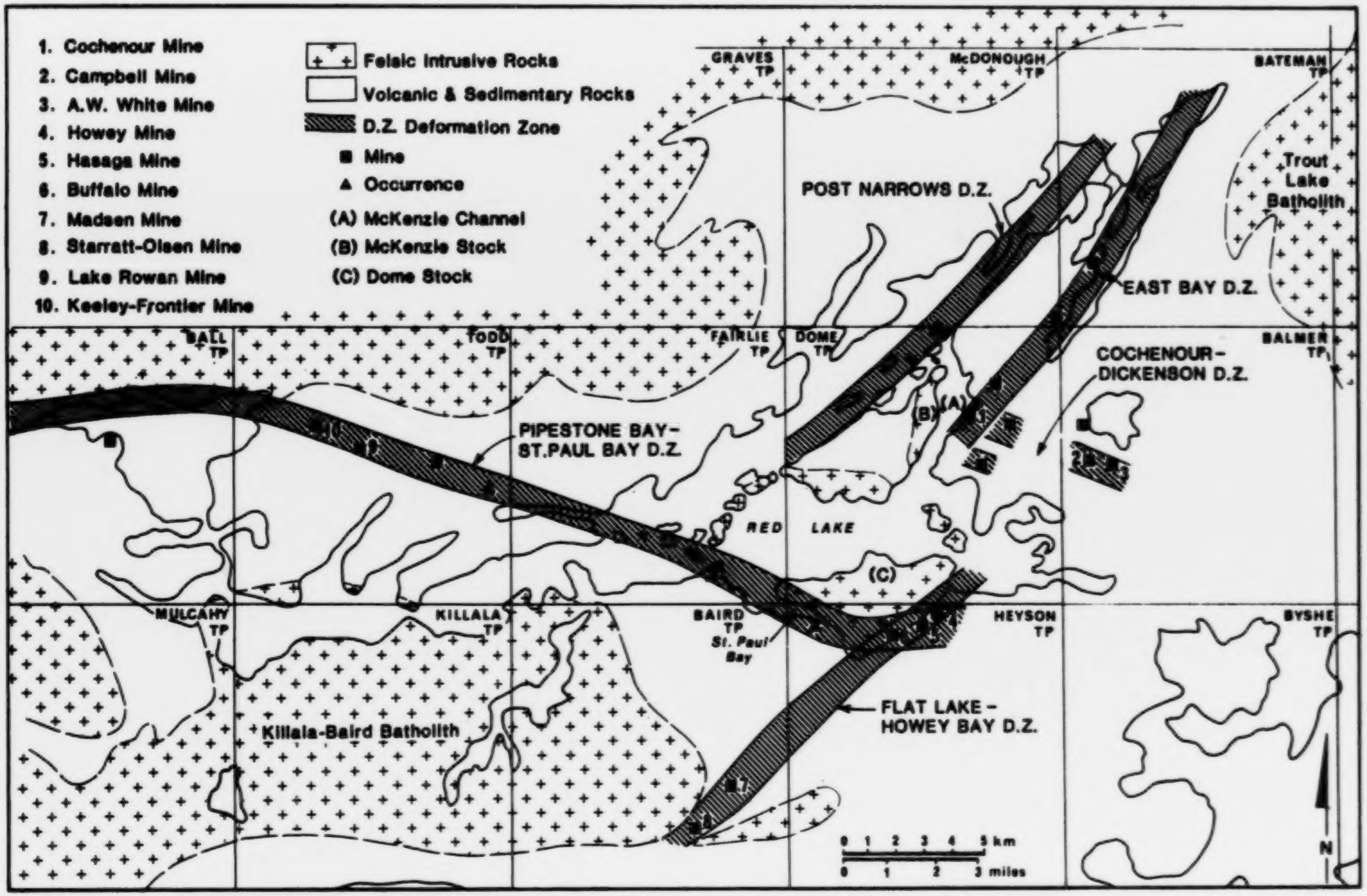
1. Cochenour Mine
2. Campbell Mine
3. A.W. White Mine
4. Howey Mine
5. Hasaga Mine
6. Buffalo Mine
7. Madsen Mine
8. Starratt-Olsen Mine
9. Lake Rowan Mine
10. Keeley-Frontier Mine
Felsic Intrusive Rocks
Volcanic & Sedimentary Rocks
D.Z. Deformation Zone
Mine
Occurrence
(A) McKenzie Channel
(B) McKenzie Stock
(C) Dome Stock
GRAVES TP
McDONOUGH TP
BATEMAN TP
POST NARROWS D.Z.
Trout Lake Batholith
EAST BAY D.Z.
BALL TP
TODD TP
FAIRLIE TP
DOME TP
BALMER TP
COCHENOUR-DICKENSON D.Z.
PIPESTONE BAY-ST.PAUL BAY D.Z.
(B)
(A)
RED LAKE
(C)
MULCAHY TP
KILLALA TP
BAIRD TP
St. Paul Bay
HEYSON TP
BYSHE TP
FLAT LAKE - HOWEY BAY D.Z.
Killala-Baird Batholith
0 1 2 3 4 5 km
0 1 2 3 miles
N

Figure 1. Simplified geological map of the Red Lake study area.

formation Zone). The combined results of these studies are now suggesting that the highly altered areas of the Red Lake camp occur in close spatial association with a system of linear deformation zones which cross-cut the belt on a regional scale (Figure 1). Most of the volcanic-hosted, past- and present-producing mines occur in highly altered rocks within or adjacent to these zones. It has yet to be determined whether mineralized structures which occur in major intrusive rocks (e.g. Dome and McKenzie stocks) are related to these deformation zones.

Work in the Eastern Section (Andrews, this volume) indicates that carbonatization is relatively widespread but spatially controlled by the East Bay and Cochenour-Dickenson Deformation Zones. Silicification and the occurrence of sericite, chlorite, and especially biotite appear to be more localized and possibly more closely associated with gold mineralization. A large thermal aureole associated with the Trout Lake batholith extends west and southwest towards the area of highly altered rocks. The relationship between hydrothermal alteration and metamorphic processes is currently being examined. This year detailed geological mapping and lithogeochemical sampling were conducted in the East Bay Deformation Zone in order to determine its structural and alteration characteristics and significance to mineralization. A substantial amount of time was spent investigating these features as they manifest in the underground workings of the Cochenour Mine (Wilanour Resources Limited). Detailed structural studies were initiated on the Cochenour-Dickenson Deformation Zone.

In the Madsen area, M.E. Durocher has shown that alteration and gold mineralization are focused in bands of highly deformed mafic flow rocks previously thought to be tuffaceous units (e.g. Austin Tuff). Here there is definitive evidence that alteration preceded a regional metamorphic event which is probably related to the emplacement of the Killala-Baird batholith, located to the west. The relatively early alteration of basalts caused depletion of Na_2O, MgO, and CaO and enrichment of SiO_2 and K_2O. Similar chemical signatures occur in altered, mineralized rocks in the Eastern Section (Pirie 1981; Andrews and Wallace 1983) and in the western part of the belt, in the vicinity of Pipestone Bay (Wallace 1982). In the Madsen/Starratt-Olsen area, metamorphic overprinting of these altered basalts resulted in the generation of alumino-silicate assemblages including staurolite, andalusite, and cordierite.

This year, M.E. Durocher completed geological studies in the Madsen/Starratt-Olsen area and initiated geological mapping and lithogeochemical sampling in the vicinity of of the Buffalo, Hasaga, and Howey former producers (Figure1). Structures in the latter area are similar and compatible with those in the Madsen/Starratt-Olsen area, indicating that both are part of a major deformation zone. This is referred to as the Flat Lake-Howey Bay Deformation Zone (Durocher and Hugon, this volume).

On the basis of reconnaissance work by Wallace (1982), M.E. Durocher, assisted by P. Burchell, extended his studies westward to initiate geological mapping and lithogeochemical sampling in the vicinity of the Keeley-Frontier (formerly Mount Jamie) and Lake Rowan past producers. This represents the first detailed documentation and characterization of the little-known gold deposits located at the western end of the Red Lake belt. Preliminary field results suggest that the geological environment of these deposits is comparable to that of the Madsen/Starratt-Olsen area. The highly deformed host basalts have been subjected to alteration followed by metamorphism resulting in the generation of alumino-silicate mineral assemblages. Evidence suggests that this area may constitute part of a linear deformation zone of regional proportions, extending from west of Pipestone Bay in Ball Township to St. Paul Bay in Fairlie Township and hosting a number of past-producing gold mines and occurrences (Durocher and Burchell, this volume).

Structure

As described above, work to date in the Red Lake belt suggests that a distinct spatial relationship exists between major deformation zones and the location of alteration and gold mineralization. On a smaller scale it is well known that the actual occurrence of individual deposits is controlled by various types of local structures. It is therefore essential to understand the relationship between local and regional scale structures and their significance to mineralization. In recognition of this, detailed structural studies were initiated this year in selected areas of the belt in co-ordination with the ongoing projects of Henry Wallace, M.E. Durocher, and A.J. Andrews.

In the initial work certain emphasis was placed on defining the structural characteristics of the deformation zones discussed above. This included detailed structural analyses of: (a) the Flat Lake-Howey Bay Deformation Zone by H. Hugon (OGRF, W.M. Schwertdner, University of Toronto); and (b) an area in Dome and McDonough Townships, including the Post Narrows and Cochenour-Dickenson Deformation Zones, by P. Berger (OGRF, J.M. Summers, Queen's University). Initial work on the Pipestone Bay-St. Paul Bay Deformation Zone is being conducted by M.E. Durocher and P. Burchell (this volume) and on the East Bay and Cochenour-Dickenson Deformation Zones by A.J. Andrews (this volume).

In general, the deformation zones appear to be large shear systems, 1 to 3 km in width, 10s of kilometres in strike length, and often parallel or sub-parallel to stratigraphy. At any single location within a system, the deformation is characterized by multiple, discrete shear zones (centimetres to metres in width) separated by narrow domains of relatively undeformed rocks. The structural features of the Flat Lake-Howey Bay Deformation Zone have been well documented as a sinistral shear system (Durocher and Hugon, this volume). As yet, the other deformation zones outlined on Figure 1 have been defined only on a preliminary basis and their boundaries are approximate.

A detailed structural study was conducted in selected mineralized and non-mineralized areas of the Cochenour Mine by M.M. Sanborn (OGS-supported M.Sc. thesis, University of Toronto). This study is an attempt to identify local structural controls of mineralization in the context of the regional deformation zone which hosts them.

In co-ordination with OGS efforts in the Red Lake area, an independent structural study was commenced this year by Bruce Wilson (Ph.D. thesis, Queen's University, Kingston). Initial work involved general reconnaissance mapping of structures throughout the belt with some focus of attention in Baird and Fairlie Townships.

Geochronology

This year a major effort to determine the relative age(s) of gold mineralization on the basis of U-Pb zircon analysis was initiated in cooperation with F. Corfu (Geochronologist, Royal Ontario Museum, Toronto). Samples were collected in both the Eastern Section and the Flat Lake-Howey Bay Deformation Zone (Andrews, this volume). These data will be considered in the context of previous U-Pb determinations, recently obtained in the area as part of a regional, stratigraphic study (F. Corfu, Geochronologist, Royal Ontario Museum, Toronto, personal communication, 1983, Henry Wallace, Geologist, Ontario Geological Survey, Toronto, personal communication, 1983). They should provide insight as to whether gold mineralization is the result of: (a) a complex, multistage process spanning a significant period of geological time; or (b) a single, unique event affecting a broad area.

This work is part of a comprehensive geochronological program to date deposits in major gold camps of Ontario (Marmont, this volume).

Fluid Inclusion-Stable Isotopic Studies

The OGS supplied logistical support to Dr. P. Brown and J. Lakind (University of Wisconsin, Madison, U.S.A.) to conduct a preliminary fluid inclusion-stable isotopic reconnaissance study of selected mineralized quartz veins in the area (Andrews, this volume). These data will provide preliminary information as to the physical-chemical conditions attending gold mineralization over a broad area. In combination with the geochronological data they should provide insight as to the complexity or uniformity of the mineralization process as a whole.

Future Work

The multidisciplinary, district scale approach to this project will continue on the basis of focused, co-ordinated studies in critical areas of the belt. In the near future emphasis will be placed on defining the pattern and nature of deformation zones, their relationship to each other, and their significance with respect to alteration, mineralization, and the structural history of the belt.

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No. 47 Alteration, Metamorphism, and Structure Associated with Archean, Volcanic-Hosted Gold Deposits, Red Lake District

A.J. Andrews[1]

Introduction

The purpose of this study is to examine the distribution, nature, and history of alteration and metamorphism in the Red Lake belt and to determine how these processes relate, both spatially and temporally, to gold mineralization, within the context of regional structure and stratigraphy (Andrews 1982). As noted in Andrews (1982), the Red Lake belt is particularly amenable to such study because of an excellent base of recently completed lithological mapping. The initial focus of the study, which commenced in 1982, is the "Eastern Section" of the belt, including Balmer, Dome, Bateman, and McDonough Townships, a most important area in terms of historic production and present mining activity.

Studies conducted during the 1983 field season involved:

1. continuation of regional geological mapping and lithogeochemical sampling to define the distribution and nature of highly altered rocks as related to original stratigraphic and structural patterns
2. detailed alteration studies along the East Bay Deformation Zone
3. detailed lithological and structural mapping and lithogeochemical sampling on the Marcus and Wilmar Properties, part of the Cochenour-Dickenson Deformation Zone
4. sampling for radiometric age-dating of gold deposits
5. providing direction and logistical support for fluid inclusion-stable isotopic studies

Complementary studies are being conducted in the central and western areas of the Red Lake belt (Durocher and Hugon, this volume; Durocher and Burchell, this volume).

Regional Structural Setting

This year's field studies have served to reinforce preliminary observations of 1982 (Andrews and Wallace 1983); that is, the Eastern Section of the Red Lake belt may be subdivided into 3 stratigraphic-structural domains and a system of major deformation zones (Figure 1).

The stratigraphic-structural domains consist of what appear to be monoclinal, volcanic-sedimentary sequences (tight, internal folding is probable) with distinct, planar fabrics or cleavages which usually are parallel or subparallel to stratigraphy. As indicated on Figure 1, the East Bay Deformation Zone forms a major domain boundary. To the west of this zone, the first domain is defined by northeast-trending stratigraphy, dipping northwest. To the east of this zone, the second domain exhibits northwest-trending stratigraphy with southwesterly dips (Dome and Balmer Townships). In Bateman Township, the third domain exhibits northeast-trending stratigraphy, more-or-less conforming to the contact configuration of the Trout Lake Batholith. Definitive indicators of stratigraphic tops are rarely exposed, and as yet, no evidence has been found to indicate with confidence the presence of a regional scale, southwest-plunging antiform in this area, as tentatively suggested by Pirie (1981) and Andrews and Wallace (1983). It is possible that these domains are juxtaposed along major deformation zones.

The deformation zones have been defined only on a preliminary basis and their boundaries, as illustrated on Figure 1, are approximate. In general, they occur as linear belts, 1 to 3 km in width and 10s of kilometres in strike length, and are usually parallel or sub-parallel to stratigraphy. Internally, they consist of multiple, discrete shear zones (centimetres to metres in width) separated by narrow domains of less deformed rocks. The East Bay Deformation Zone is located along and adjacent to the East Bay Serpentinite. It trends northeast and forms a major domain boundary as described above. Preliminary structural analysis of this zone suggests the existence of a regional scale, sinistral shear system (Andrews and Wallace 1983; Berger and Summers, this volume). A much less well defined system, referred to as the Cochenour-Dickenson Deformation Zone, occurs in central Dome and Balmer Townships. This area is characterized by a pervasive, penetrative, planar fabric, and discrete zones of intense shearing and mylonitization, all trending about 120° ± 10°. Structural analyses were initiated this year on the Marcus and Wilmar Properties and suggest, on a preliminary basis, that this zone may represent a large shear

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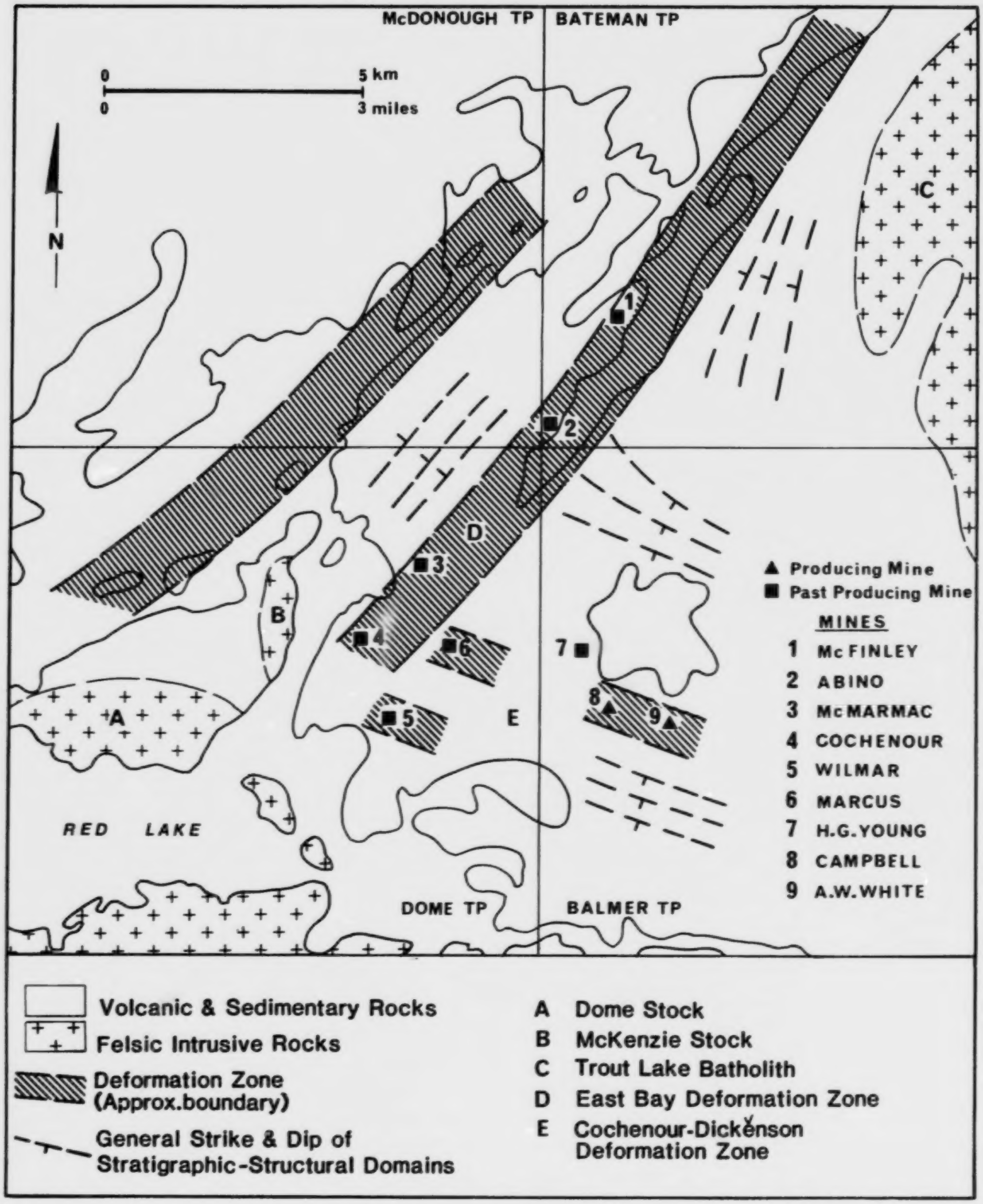
McDONOUGH TP
BATEMAN TP
DOME TP
BALMER TP
0
5 km
0
3 miles
N
A
B
C
D
E
1
2
3
4
5
6
7
8
9
RED LAKE
▲ Producing Mine
■ Past Producing Mine
MINES
1 Mc FINLEY
2 ABINO
3 McMARMAC
4 COCHENOUR
5 WILMAR
6 MARCUS
7 H.G. YOUNG
8 CAMPBELL
9 A.W. WHITE
Volcanic & Sedimentary Rocks
Felsic Intrusive Rocks
Deformation Zone (Approx. boundary)
General Strike & Dip of Stratigraphic-Structural Domains
A Dome Stock
B McKenzie Stock
C Trout Lake Batholith
D East Bay Deformation Zone
E Cochenour-Dickenson Deformation Zone

Figure 1. The Red Lake study area, illustrating the trends of the stratigraphic-structural domains and the occurrence of deformation zones. The boundaries of the deformation zones are approximate.

system. Minor structures suggest a strong component of dextral displacement. A major, northwest-trending shear system has been described along the East South C, South C, and A zones of the A.W. White (formerly Dickenson) and Campbell Mines (Lavigne and Crocket 1983). As yet, the boundaries of the Cochenour-Dickenson Deformation Zone have not been well defined, a situation which is partly due to the poor exposure in this area. As illustrated on Figure 1, it is not yet known whether this zone consists of multiple, parallel deformation zones or 1 large deformation zone of significant width. The East Bay and Cochenour-Dickenson Zones converge in the northeastern part of Dome Township. Preliminary field observations by Berger and Summers (this volume) suggest that the northwest-trending (120° ± 10°) fabrics were established later than those of the northeast-trending system.

Alteration

The distribution of highly altered rocks in the area (*see* Andrews 1982, Figure 1) appears related to the configuration of the East Bay and Cochenour-Dickenson Deformation Zones. All the volcanic-hosted, past- and present-producing mines in the Eastern Section of the Red Lake belt occur in close spatial association with highly altered rocks within the deformation zones. In order to examine this relationship in more detail, alteration studies were focused this year on the environs of the East Bay Deformation Zone (a major goal in this respect is to determine whether alteration can be employed as a useful pathfinder to ore within the deformation zones). This study consisted of detailed mapping and lithogeochemical sampling in selected areas of the Cochenour Mine (coordinated with the structural study by Sanborn, this volume); the Abino decline; surface outcrops and stripped areas on the Marcus and Redcon Properties; and via examination of drillcore recently obtained from the Redcon and McFinley Properties.

Within and immediately adjacent to the deformation zones, carbonatization appears widespread while biotite, sericite, and chlorite are more localized. Biotite occurs as an important secondary phase on the McFinley Property, the Redcon Property, and in the Campbell and A.W. White Mines. In both of these mines, biotite appears to occur in elongate envelopes surrounding silicified zones which host gold mineralization (R. Church, Chief Geologist, Campbell Red Lake Mines Limited, and J. Rogers, Mine Geologist, Dickenson Mines Limited, personal communications, 1983). Chlorite, sericite, and carbonate are more significant in the area of the Cochenour, Wilmar, and McMarmac Mines. In general, mineralized areas are characterized by broad haloes (100s of metres in width) of moderate but pervasive silicification. SiO_2 contents of pillow basalts in these areas typically fall within the 50 to 60 weight percent range. Intense brecciation and silica flooding characterize rocks in the immediate vicinity (metres to 10s of metres) of ore zones, accompanied by numerous quartz and Fe-dolomite veins. Gold, often with fine arsenopyrite, occurs disseminated within the intensely silicified areas and as higher grade zones within the veins.

Metamorphism

Preliminary observations from 1982 suggested that an extensive contact aureole exists in the volcanic rocks surrounding the Trout Lake Batholith (Figure 1). The configuration of this aureole and the possible link of such metamorphic processes with alteration and gold mineralization is currently under investigation on the basis of detailed petrographic and mineralogical studies.

Geochronology

One of the principal goals of this project is to provide insight as to the timing of gold mineralization within the context of the volcanic, metamorphic, alteration, and structural history of the enclosing rocks. F. Corfu (Geochronologist, Royal Ontario Museum, Toronto, personal communication, 1983) and H. Wallace (Geologist, Ontario Geological Survey, Toronto, personal communication, 1983) have already conducted considerable U-Pb zircon age dating in the Red Lake area (Figure 2). These data have provided useful constraints on interpretations of the stratigraphy and geological history of the belt as a whole.

This year, in co-operation with the Geochronology Laboratory of the Royal Ontario Museum in Toronto, a comprehensive program of zircon age dating was initiated to determine the relative age(s) of mineralization in major gold camps of Ontario (Marmont, this volume). In the Red Lake area, sampling was conducted at 10 carefully selected sites in the Eastern Section and the Flat Lake-Howey Bay Deformation Zone (Figure 2, Table 1). Three samples (4, 6, and 7, Table 1) will be used to further delineate the volcanic stratigraphy which hosts the Campbell and A.W. White Mines in Balmer Township and one sample (10) was taken to provide an initial age determination on the Killala-Baird batholith. All other samples were obtained from rock formations which either host gold mineralization or have well documented relationships to it. The resulting data will be of importance in addressing the problem of whether gold mineralization in the Red Lake area occurred as a single unique event affecting a broad area, or a multistage process spanning a significant period of geological time.

Fluid Inclusion-Stable Isotope Studies

Sampling for fluid inclusion and stable isotopic studies was conducted by P. Brown and J. Lakind (University of Wisconsin, Madison) under Ontario Geological Survey direction and logistical support. This is viewed as a recon-

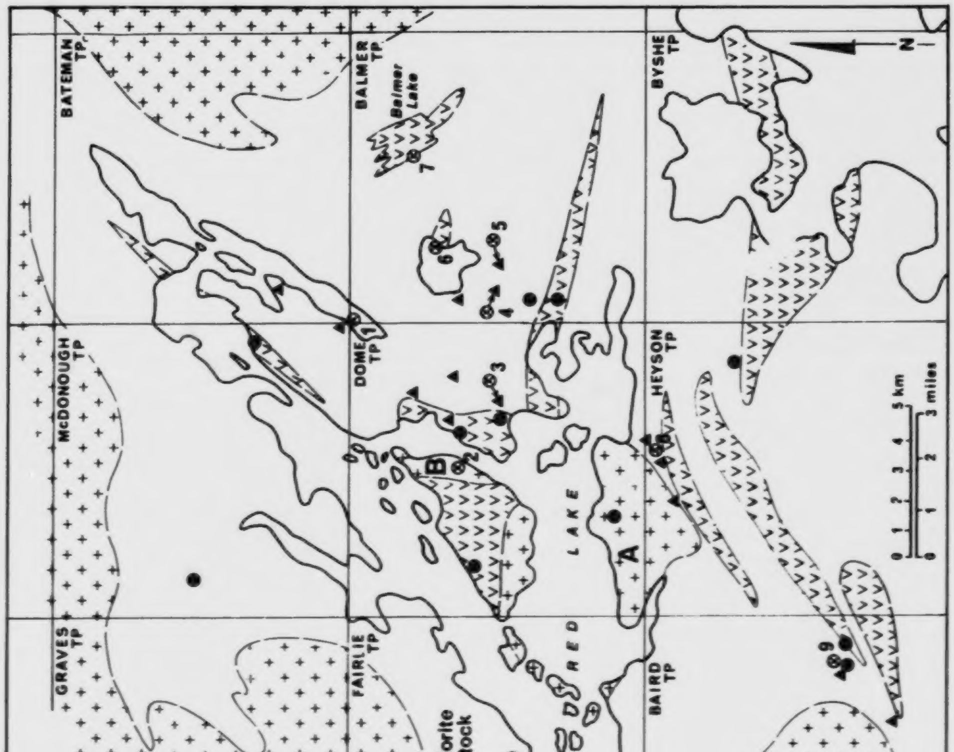
Mafic to Intermediate Volcanic Rocks & Sediments
Felsic Volcanic Rocks
Felsic Intrusive Rocks
▲ Past & Present Producing Mines
● Previous Sample Site (Corfu & Wallace, in prep.)
⊗ Present Sample Site
A Dome Stock
B McKenzie Stock
C Killala-Baird Batholith
BATEMAN TP
McDONOUGH TP
GRAVES TP
BALMER TP
Balmer Lake
DOME TP
FAIRLIE TP
TODD TP
BALL TP
BYSHE TP
HEYSON TP
BAIRD TP
KILLALA TP
MULCAHY TP
Diorite Stock
RED LAKE
A
B
C
1
2
3
4
5
6
7
8
9
10
0 1 2 3 4 5 km
0 1 2 3 miles
N

Figure 2. Simplified geological map of the Red Lake belt showing sample sites for U-Pb zircon analysis (refer also to Table 1).

TABLE 1 DESCRIPTION OF SAMPLE LOCATIONS FOR GEOCHRONOLOGY

SAMPLE NO.	LOCATION	ROCK TYPE	DESCRIPTION
1.	Abino decline (Goldquest)	granodiorite	gold host
2.	McKenzie stock	granodiorite	gold host
3.	Wilmar Mine (Wilanour Resources)	granodiorite	gold host
4.	Campbell Mine	felsic flows	stratigraphy
5.	A.W. White Mine	diorite quartz-feldspar porphyry dikes	gold host post-ore
6.	Balmer Lake	quartz-feldspar porphyry	stratigraphy
7.	NE Balmer Township	quartz-feldspar porphyry	stratigraphy
8.	Howey and Hasaga Mines	felsic dike	gold host
9.	Madsen Mine	felsic dike	post-ore
10.	Killala Township	granodiorite	batholith

naissance study with particular attention directed to the environment of intermediate to felsic intrusive rocks hosting mineralized quartz veins. Sampling sites included the Dome stock, McKenzie stock, Wilmar granodiorite, Abino granodiorite, and a small diorite stock in Fairlie Township (Figure 2, Table 1). Fluid inclusions in the quartz will be examined by conventional petrographic techniques and light stable isotope (O, H) analysis. Petrographic and light stable isotope analyses will be conducted on vein constituents and alteration minerals in the host wall rocks. This study represents a first attempt at defining the nature of fluids and the physical-chemical conditions attending gold mineralization in this particular environment of the Red Lake camp. The data will provide a useful adjunct to our radiometric age dating, and will also serve as a useful preface to more focused geochemical studies to be initiated in the near future.

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No. 48 Structural Geology and Hydrothermal Alteration in the Flat Lake-Howey Bay Deformation Zone, Red Lake Area

Marcel E. Durocher[1] and H. Hugon[2]

Introduction

Field work in 1983 consisted of detailed mapping in Baird and Heyson Townships in the vicinity of the Madsen, Starratt-Olsen, Hasaga, and Howey former gold producers. Detailed mapping (Durocher and van Haaften 1982) has delineated the lithological units in this area. The objectives of the present work are to: a) outline and characterize the alteration haloes associated with these deposits; and b) determine their structural setting.

General Geology

The general geology in Baird and Heyson Townships is shown in Figure 1. Rocks in this area can be grouped into 2 major sequences: a lower tholeiitic-komatiitic sequence and an upper calcalkalic sequence (Pirie 1980; Wallace 1982; Durocher 1983). The 2 sequences are part of a large domal structure centred to the north of the study area between the Killala-Baird Batholith and the Dome Stock.

The strike and dip of the rock units in both sequences vary systematically across the study area, defining a large open S-shaped flexure. In the vicinity of the Starratt-Olsen Mine, rock units strike 055° to 060° and dip 70° southeast. Close to the Madsen Mine, the strike is 030° and the dip is 65° southeast. Two kilometres northeast of the Madsen Mine, the strike is 045° and the dip is 70° to 75° to the southeast. In the vicinity of the Howey and Hasaga Mines, rocks strike 065° and dip 80° southeast. Foliation in the area generally strikes northeast and dips moderately to steeply southeast.

The tholeiitic-komatiitic sequence can be subdivided into lower and upper parts which may themselves be separate sequences of different ages. The lower part of the sequence comprises dominantly ultramafic and mafic flows whereas the upper part comprises dominantly mafic to intermediate volcanic rocks (Durocher 1983). Numerous gabbro sills and/or dikes are present in both parts of the sequence.

The calcalkalic sequence comprises intermediate to felsic flows and pyroclastic rocks.

The youngest rocks in the area are the granodiorites of the Killala-Baird Batholith and the Faulkenham Lake and Dome Stocks.

Ore Deposits and Hydrothermal Alteration

Mapping has outlined several bands of intensely altered and deformed rocks (Figure 1). Those in the southwestern part of the area have been called "altered tuff" by previous workers (Horwood 1945; Ferguson 1965; Durocher 1983). The Madsen and Starratt-Olsen Mines are located in one such band, called the "Austin tuff".

At several localities in the vicinity of the Madsen Mine, gradations from relatively unaltered and undeformed pillowed mafic flows to highly altered and deformed "tuffs" have been observed; adequate exposure of the progressive steps present indicates that these bands of highly altered and deformed rocks were produced by intense alteration and deformation of pillowed mafic flows. The gradation takes place over approximately 100 m and is characterized by an increase in the fracture density and by an increase in the intensity and amount of alteration along the fractures. The most intensely altered rocks are also highly sheared.

Comparison of the immobile elements' (Co, Cr, Ni, Sc, Nb, V, Y, Zr, Al, Ti, and P) abundances in relatively unaltered and undeformed mafic flows, with abundances in rocks from the highly altered and deformed bands, is consistent with the highly altered and deformed rocks initially being mafic flows.

Southwest of the Buffalo Mine, rocks in these highly altered and deformed bands have been depleted in Na_2O, MgO, and CaO, and enriched in SiO_2, K_2O, Sb, Li, B, and Ba. In the vicinity of the Madsen and Starratt-Olsen Mines these patterns are enhanced and there has also been addition of As, S, Zn, Cu, Hg, and Au. The CO_2 content of these highly altered and deformed rocks appears to be directly related to the metamorphic grade. In areas where

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[2] Post-Doctoral Fellow, Department of Geology, University of Toronto, Toronto.

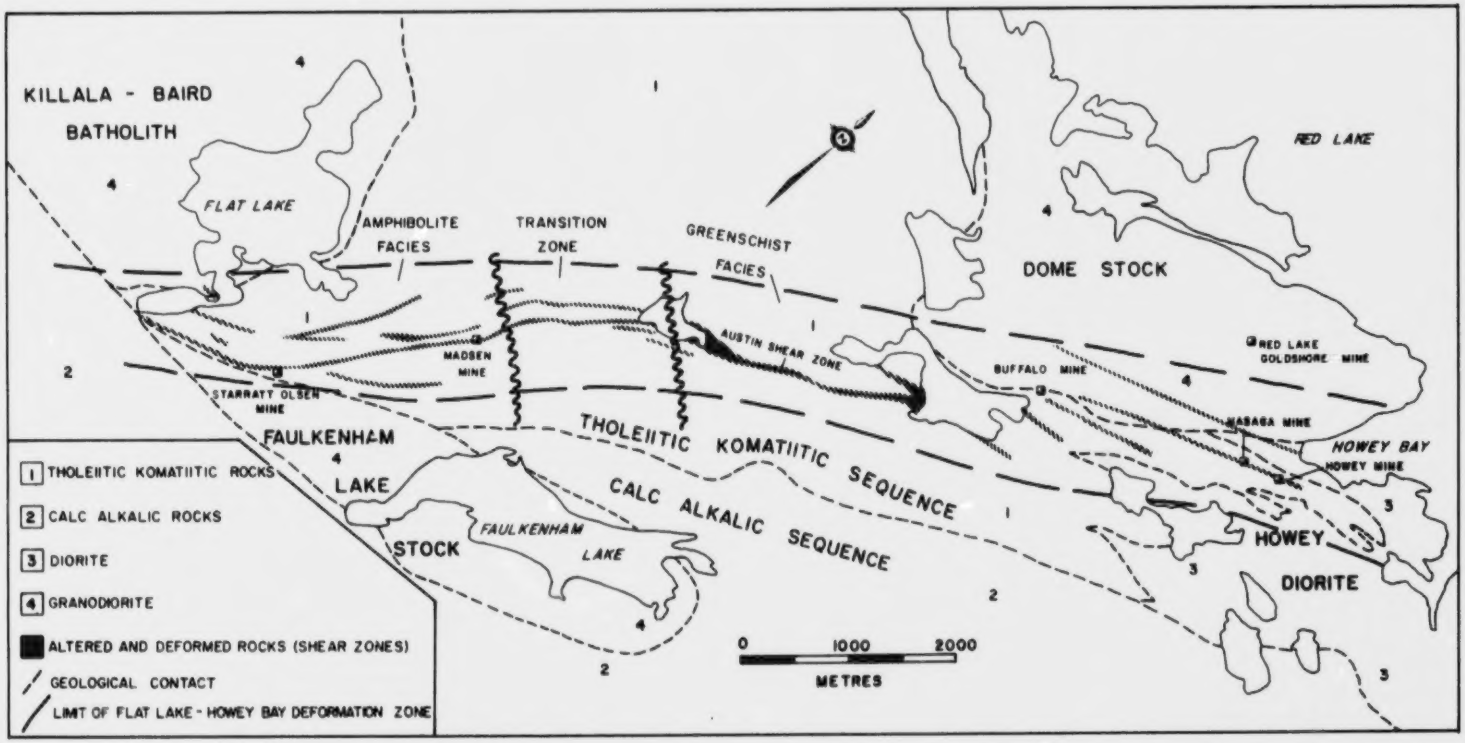
KILLALA - BAIRD BATHOLITH
FLAT LAKE
AMPHIBOLITE FACIES
TRANSITION ZONE
GREENSCHIST FACIES
DOME STOCK
RED LAKE
MADSEN MINE
STARRATT OLSEN MINE
AUSTIN SHEAR ZONE
BUFFALO MINE
RED LAKE GOLDSHORE MINE
MASAGA MINE
HOWEY BAY
HOWEY MINE
FAULKENHAM LAKE STOCK
FAULKENHAM LAKE
THOLEIITIC KOMATIITIC SEQUENCE
CALC ALKALIC SEQUENCE
HOWEY DIORITE
0
1000
2000
METRES
1 THOLEIITIC KOMATIITIC ROCKS
2 CALC ALKALIC ROCKS
3 DIORITE
4 GRANODIORITE
ALTERED AND DEFORMED ROCKS (SHEAR ZONES)
GEOLOGICAL CONTACT
LIMIT OF FLAT LAKE - HOWEY BAY DEFORMATION ZONE

Figure 1. General geology of the Flat Lake-Howey Bay Deformation Zone (after Ferguson 1965, 1968).

the grade of metamorphism has attained amphibolite facies they have been depleted in CO_2, whereas in areas where the grade of metamorphism has reached greenschist facies, they have been enriched in CO_2.

The Buffalo Mine straddles the contact between the southern edge of the Dome Stock and mafic volcanic rocks. Gold mineralization occurs in quartz-tourmaline veins in the granodiorite of the Dome Stock. Both the volcanic rocks and the granodiorite in the vicinity of the mine are highly altered and deformed. All rocks in the vicinity of the mine have been carbonatized. The granodiorite adjacent to the quartz-tourmaline veins contains abundant pyrite, and has been silicified in places.

The Hasaga and Howey Mines are located in a deformed and altered quartz porphyry dike enclosed by highly sheared and altered mafic volcanic rocks. In the vicinity of the mines, the quartz porphyry dike has been highly sericitized (Horwood 1945). The adjacent mafic volcanic rocks have been bleached to a pale grey colour.

Lithogeochemical studies of alteration and dispersion patterns associated with the Buffalo, Hasaga, and Howey Mines are in progress.

Metamorphism

Metamorphic grade varies systematically across the area. In the vicinity of the Starratt-Olsen and Madsen Mines, the metamorphic grade has attained middle amphibolite facies. In the northeastern part of the area, the grade of metamorphism has reached greenschist facies. The transition between the 2 grades of metamorphism takes place in a 1.5 km wide zone located approximately 0.5 km northeast of the Madsen Mine (Figure 1). Within the metamorphic transition zone, higher grade metamorphic mineral assemblages occur considerably farther to the northeast in the bands of intensely altered and deformed rocks than in adjacent relatively unaltered and undeformed equivalent rocks.

In the vicinity of the Madsen and Starratt-Olsen Mines, relatively undeformed and unaltered pillowed mafic flows are comprised of hornblende, plagioclase, and quartz. The highly altered and deformed equivalents are comprised of variable proportions of andalusite, cordierite, staurolite, garnet, cummingtonite, muscovite, biotite, and quartz.

In the metamorphic transition zone, relatively unaltered and undeformed pillowed mafic flows are comprised of variable proportions of actinolite, chlorite, albite, and epidote. Highly altered and deformed equivalents are comprised of variable proportions of andalusite, staurolite, garnet, cummingtonite, sericite, biotite, and quartz.

To the northeast of the metamorphic transition zone relatively fresh mafic flows comprise variable proportions of actinolite, chlorite, albite, and epidote. Highly altered and deformed equivalents comprise sericite, biotite, quartz, and iron-carbonate.

Structural Geology

Preliminary results of a structural study in the Madsen-Starratt-Olsen Mines area indicate that the narrow bands of intensely altered and deformed mafic flows described above are transcurrent shear zones.

The shear zones vary in width from 1 to 100 m, and are characterized by the presence of a well defined foliation containing a subhorizontal stretch lineation. Minor structures also present in those shear zones include flow folds, buckle folds, unfolded folds, strain shadows around clasts and crystals, and small-scale ductile shear zones. These structures are compatible with left-lateral movement along the shear zones.

The domains between these shear zones are either massive, or foliated with a subvertical, down-dip stretch lineation.

Of these shear zones, the so-called "Austin tuff" is the most important. It varies in thickness from 10 to 100 m and has been traced along strike for at least 9 km. It has absorbed most of the left-lateral deformation in the area. The layering observed in this shear zone is of tectonic origin and not primary layering, as described by Horwood (1945) and Ferguson (1965). It is suggested that this band of highly altered and deformed rocks be renamed the Austin Shear Zone.

Structures observed in rocks in the vicinity of the Howey and Hasaga former gold producers are similar to and consistent with those observed in the vicinity of the Madsen-Starratt-Olsen former producers, indicating that left-lateral shear zones are also present in the Howey-Hasaga area.

These shear zones are part of a larger deformation zone, called here the Flat Lake-Howey Bay Deformation Zone, which extends from Flat Lake to Howey Bay and is approximately 1.5 km wide. The tentative boundaries of this deformation zone are shown in Figure 1.

Although the Buffalo Mine is located in the Flat Lake-Howey Bay Deformation Zone, it is not known at present whether the gold mineralization is related to the left-lateral shear zones of the Flat Lake-Howey Bay Deformation Zone, or the later right-lateral shear zones of the Pipestone Bay-St. Paul Bay Deformation Zone which also extends into this area from the northwest. Similarly, it is not known at present whether or not the shear zones at the Red Lake Goldshore Mine are of the same generation as those in the Flat Lake-Howey Bay Deformation Zone. Additional work needs to be done to better define the boundaries of this deformation zone.

Discussion

In the Madsen-Starratt-Olsen Mines area the relative timing of hydrothermal alteration can be bracketed. Volcanic rocks in both the upper and lower parts of the tholeiitic-komatiitic sequence have been altered, as are the gabbro dikes and/or sills which cut these rocks. Alteration was therefore post-gabbro sill/dike intrusion in age. Field observations and petrographic studies suggest that left-lateral shearing and metamorphism took place synchronously. Mineral assemblages and textures and structures suggest that hydrothermal alteration took place early in the metamorphic and tectonic history of this area. The presence of post-ore, undeformed granodiorite dikes indicates that hydrothermal alteration, metamorphism, and shearing preceeded the late stages of granitic intrusion.

The 4 former gold producers, the Madsen, Starratt-Olsen, Hasaga, and Howey Mines, are located in left-lateral shear zones in the Flat Lake-Howey Bay Deformation Zone. This deformation zone is approximately 1.5 km wide and contains several discrete, left-lateral shear zones separated by intervening areas of relatively unaltered and deformed rocks. Left-lateral shear zones have been observed cutting through the marginal parts of the Killala-Baird Batholith (Bruce Wilson, Graduate Student, Queens University, Kingston, Ontario, personal communication, 1983) and the Dome Stock, indicating that the deformation zone and hence the gold mineralization is late in the geological history of this area.

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No. 49 Structural Geology, Hydrothermal Alteration, Metamorphism, and Gold Mineralization in the Pipestone Bay-St. Paul Bay Deformation Zone, Red Lake

Marcel E. Durocher[1] and P. Burchell[2]

Introduction

Field work during 1983 has outlined a major deformation zone in the western and central parts of the Red Lake "greenstone belt" (Horwood 1945; Ferguson 1965, 1966, 1968). It is 1 to 2 km wide and at least 36 km in length and extends from the western end of Pipestone Bay to the Howey-Hasaga area in Heyson Township (Figure 1). The style of deformation in this zone is similar to that in the Flat Lake-Howey Bay Deformation Zone (*see* Durocher and Hugon, this volume) which hosts major gold mineralization, including the past producing Madsen Mine. This zone is therefore considered to be a potential target area for further gold mineralization.

Structural Geology

At any one locality, the zone is characterized by several discrete and closely spaced shear zones separated by narrow domains of relatively undeformed rocks. The sense of shearing along these shear zones is dextral. Small conjugate left-lateral shear zones are locally well developed (Bruce Wilson, Graduate Student, Queen's

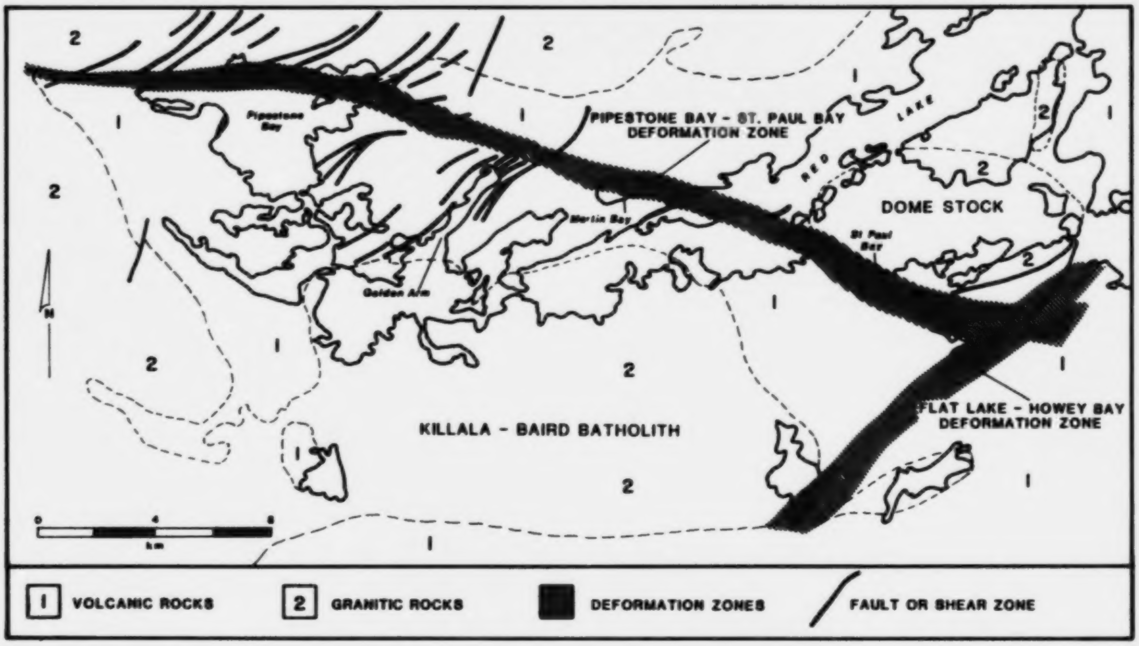
2
2
1
1
Pipestone Bay
PIPESTONE BAY - ST. PAUL BAY DEFORMATION ZONE
RED LAKE
2
1
2
1
2
DOME STOCK
Martin Bay
St Paul Bay
2
Golden Arm
N
1
2
1
2
1
FLAT LAKE - HOWEY BAY DEFORMATION ZONE
KILLALA - BAIRD BATHOLITH
1
2
1
0
4
8
km
1
1 VOLCANIC ROCKS
2 GRANITIC ROCKS
DEFORMATION ZONES
FAULT OR SHEAR ZONE

Figure 1. Location of the Pipestone Bay-St. Paul Bay Deformation Zone.

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University, Kingston, Ontario, personal communication, 1983). They occur in the intervening, relatively undeformed rocks between the right-lateral shear zones.

In the area between Golden Arm and Martin Bay, there is an apparent cumulative right-lateral displacement in the order of 2 km along the deformation zone (Henry Wallace, Geologist, Ontario Geological Survey, Toronto, personal communication, 1983). The curvilinear symmetry of the northeast-southwest striking lineaments, shear zones, and faults in the vicinity of this deformation zone is also consistent with right-lateral displacement along the zone.

Right-lateral shear zones that are part of this deformation zone have also been observed in the Dome Stock in the St. Paul Bay area and in the Buffalo Mine (Bruce Wilson, personal communication, 1983). Small right-lateral shear zones have also been observed in the Dome Stock, Howey Diorite, and volcanic rocks in the vicinity of the Howey and Hasaga Mines. In this area, they are later than the left-lateral shear zones of the Flat Lake-Howey Bay Deformation Zone.

Hydrothermal Alteration and Metamorphism

The nature and distribution of hydrothermal alteration associated with gold mineralization in this deformation zone is very similar to that in the Flat Lake-Howey Bay Deformation Zone (*see* Durocher and Hugon, this volume).

North of Golden Arm, where the grade of metamorphism has attained amphibolite facies (Figure 2), highly altered and deformed mafic flows are composed of variable proportions of andalusite, garnet, biotite, sericite, and staurolite (Wallace 1982). Unaltered and undeformed equivalents are composed of variable proportions of hornblende, plagioclase, and quartz. Highly altered and deformed felsic volcanic rocks comprise muscovite and quartz. With the exception of a small lens in the vicinity of the Lake Rowan Mine, Fe-carbonate is conspicuously absent from these highly altered and deformed rocks.

In the metamorphic transition zone, northeast of Golden Arm (Figure 2), highly altered mafic flows are characterized by a similar aluminous mineral assemblage. Somewhat less altered mafic volcanic rocks have been bleached to a pale grey-green colour and are locally biotitic. These rocks also contain minor amounts of calcite in places. Relatively fresh mafic volcanic rocks are dark green in colour, and appear to be composed of variable proportions of chlorite, actinolite, and saussuritized plagioclase.

Where the grade of metamorphism has attained greenschist facies (Figure 2), highly altered and deformed mafic flows have been carbonatized, and contain abun-

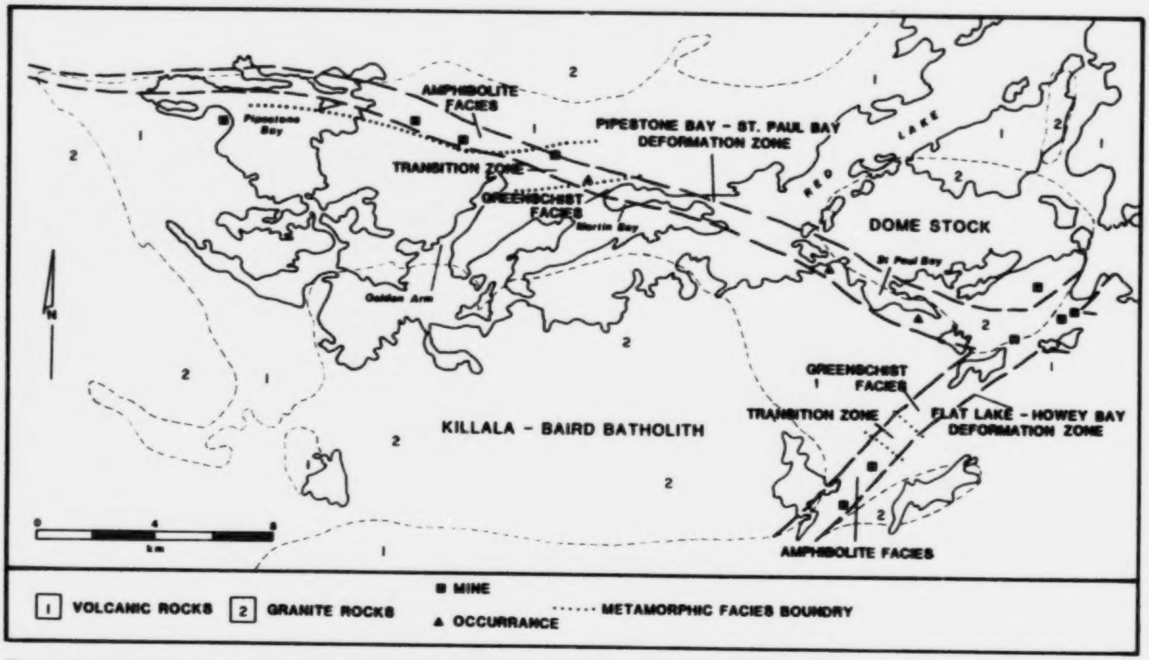
2
AMPHIBOLITE FACIES
1
PIPESTONE BAY - ST. PAUL BAY DEFORMATION ZONE
RED LAKE
Pipestone Bay
2
TRANSITION ZONE
GREENSCHIST FACIES
Martin Bay
DOME STOCK
St Paul Bay
N
Golden Arm
2
1
GREENSCHIST FACIES
TRANSITION ZONE
FLAT LAKE - HOWEY BAY DEFORMATION ZONE
KILLALA - BAIRD BATHOLITH
0
4
8
km
AMPHIBOLITE FACIES
1 VOLCANIC ROCKS
2 GRANITE ROCKS
■ MINE
▲ OCCURRANCE
······ METAMORPHIC FACIES BOUNDRY

Figure 2. Metamorphic zones within the Pipestone Bay-St. Paul Bay Deformation Zone.

dant Fe-carbonate. Relatively unaltered and undeformed mafic flows appear to comprise variable proportions of chlorite, actinolite, and saussuritized plagioclase. Highly altered and deformed felsic volcanic rocks are composed of sericite, quartz, and Fe-carbonate.

By analogy with the Flat Lake-Howey Bay Deformation Zone, the observed mineral assemblages in hydrothermally altered rocks from this deformation zone correspond to depletion in Na_2O, CaO, and MgO, and enrichment in K_2O, SiO_2, As, Sb, and Au. Highly altered rocks which have been subjected to amphibolite grade metamorphism contain very low amounts of CO_2, whereas highly altered rocks which have been affected by greenschist facies metamorphism have been greatly enriched in CO_2. Preliminary results of geochemical work by Henry Wallace (personal communcation, 1983) in the western half of the Red Lake "greenstone belt" confirm that these chemical changes have occurred.

Gold Mineralization

There are several small gold deposits known within or adjacent to the Pipestone Bay-St. Paul Bay Deformation Zone. These include the Keeley-Frontier and Lake Rowan Mines located between Golden Arm and Pipestone Bay, the Red Summit Mine located approximately 2 km northeast of Golden Arm, and possibly the Cole Mine on the western shore of Pipestone Bay. All of these deposits are quartz-vein hosted and have small, but high grade, ore reserves.

The Lake Rowan and Keeley-Frontier Mines are located in an area of highly altered and deformed rocks which extend from north of Golden Arm to the islands in the northeastern part of Pipestone Bay. To date, most of the exploration and development work in this area has concentrated upon small auriferous quartz veins. The striking similarities in style of deformation and the nature and intensity of hydrothermal alteration between this area and the area in the vicinity of the Madsen and Starratt-Olsen Mines in Baird Township suggest that this area should be explored for shear-zone hosted, Madsen type gold deposits. Lithogeochemical studies such as the study by Durocher (1983) in the Madsen-Starratt-Olsen area would be useful in outlining potential targets.

In the area immediately west of Martin Bay, gold mineralization occurs in sheared and altered mafic volcanic rocks, narrow quartz veins, and narrow quartz-carbonate zones. Significant amounts of silver, pyrite, pyrrhotite, arsenopyrite, chalcopyrite, sphalerite, and galena are closely associated with the gold mineralization in this area (Riley 1971a, 1971b, 1975).

Areas within this deformation zone containing quartz and quartz-carbonate vein systems in carbonatized mafic volcanic rocks have high potential for hosting Campbell-Dickenson type gold deposits. Wallace (1982) has outlined such an area to the south and northwest of St. Paul Bay. These quartz and quartz-carbonate vein systems extend to the northwest under the waters of Red Lake for at least 2 km. Anomalous concentrations of pyrite, pyrrhotite, sphalerite, galena, chalcopyrite, and arsenopyrite are locally associated with the gold mineralization in the area (Riley 1971a, 1971b, 1975).

Competent, relatively undeformed rocks in contact with highly deformed, incompetent rocks within the deformation zone have high potential for hosting quartz-vein type gold deposits. The auriferous quartz-tourmaline veins of the Buffalo deposit appear to be of this type. The contact between the southwestern edge of the Dome Stock and the adjacent volcanic rocks should be explored for this type of gold deposit.

Conclusions

This work has outlined a major zone of intense deformation in the Red Lake "greenstone belt" that is 1 to 2 km wide and at least 36 km in length. At any one locality, this zone is composed of several closely spaced shear zones separated by narrow domains of relatively undeformed rocks. The sense of shearing along these shear zones is dominantly right lateral.

The nature of hydrothermal alteration associated with gold mineralization in this deformation zone can be directly related to the grade of metamorphism. Where the metamorphic grade is relatively high (amphibolite facies), hydrothermally altered rocks are characterized by aluminous mineral assemblages and very low Fe-carbonate contents. In areas where the grade of metamorphism is relatively low (greenschist facies), hydrothermally altered rocks are characterized by abundant iron-bearing carbonate.

The style of gold mineralization in this deformation zone can also be related to metamorphic grade. Quartz-carbonate vein-hosted gold mineralization of the Campbell-Dickenson type is largely restricted to parts of the zone in which the grade of metamorphism is low. Areas with potential for hosting Madsen type gold deposits are largely restricted to where the metamorphic grade has attained amphibolite facies. Quartz-vein hosted gold mineralization occurs throughout the deformation zone.

Field observations suggest that hydrothermal alteration, gold mineralization, metamorphism, and development of the deformation zone are temporally very closely related. Field observations also indicate that these events occurred late in the geological history of this part of the Red Lake "greenstone belt".

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No. 50 Structural Examination of the Mineralized West Carbonate Zone, Cochenour Willans Gold Mine, Red Lake, Ontario

Mary M. Sanborn[1]

Introduction

The Cochenour Willans Gold Mine, situated in Dome Township, Red Lake Mining District (*see* Andrews and Durocher, Figure 1, this volume), was in production from 1939 to 1975, yielding some 1 131 000 ounces of gold from 2 million tons of ore. From 1963 until final shut down in 1975, development and production continued in conjunction with an extensive underground and diamond drilling exploration program. This was carried out to depth and largely into the associated Consolidated Marcus, Annco, and Wilmar Properties located to the east, south, and south-southeast of Cochenour respectively. The mine property is currently being maintained by a small support staff under the management of geologist E.W. Scherkus.

To date, a report by Kuryliw (1957) represents the only published documentation of structures and mineralization at the Cochenour Willans Mine. Until then, the complexity and intense alteration of the rocks had obscured any relationship between ore and structures. It is the intent of this study to further investigate the structural controls of mineralization with particular attention directed to the Cochenour West Carbonate Zone.

Cochenour West Carbonate Zone

The Cochenour West Carbonate Zone lies approximately 300 m southwest of the Cochenour main shaft (Figure 1, inset) and is dominated by 3 types of Archean volcanic rock. Based on mine terminology these are: a) Rhyolite-X: thought to be a completely carbonatized, silicified basalt that dominates the mine; b) Mafic Volcanic Rock: of basaltic to andesitic composition, present in the extreme west; and c) Granular Altered Rock: a chlorite-talc schist occupying a zone between the Mafic Volcanic Rock and Rhyolite-X (Figure 1). The stratigraphic sequence of the Cochenour West Carbonate Zone has been obscured by complex deformation and alteration patterns. Cherty sediments and lean banded iron formation exist throughout the drifts but are block faulted and at times rotated and are, therefore, not representative of the original stratigraphy. Occurrences of pillows within Rhyolite-X may, with careful examination, provide some information on stratigraphic top directions; however, in most cases they are somewhat deformed and therefore not reliable in this respect.

Silicified, banded carbonate veins (mainly Fe-dolomite) occur within the Granular Altered Rock and are host to the gold mineralization of the Cochenour West Carbonate Zone. Historically, these veins were thought to occur within a major zone of thrust faulting which involved considerable northward displacement, estimated at several thousand feet (Kuryliw 1957). This zone experienced a history of subsequent deformation and was the focus of later gold mineralization.

The carbonate veins extend from the 975- to the 2050-foot levels, trend between 150° and 170°, and dip gently to the southwest. They constituted the principal producing area of the Cochenour Mine during the mid-1960s. Following the production of some 86 000 tons, with an average grade of 0.351 ounce gold per ton, further exploration below the 2050-foot level indicated decreasing grades and poor ground conditions, the latter resulting from talcose rocks and intense faulting (Hutton *et al.* 1964). As a result, further exploration to depth was halted at the 2200-foot level, the lowermost level of the Cochenour Mine. For comparison, at the time of writing the lowermost producing levels at the presently active Campbell and the A.W. White (formerly Dickenson) Mines are at 3000 feet and 3350 feet below surface, respectively.

Field Observations

During the 1983 field season, detailed underground work within the Cochenour West Carbonate Zone was carried out at the 1675- and 1900-foot levels throughout approximately 5000 drift feet. This work included lithological mapping, comprehensive documentation of structural features, rock sampling, and assaying. Preliminary observations suggest that a major deformation event focused within the area of the West Carbonate Zone has produced a well defined shear zone. This conclusion is based on:

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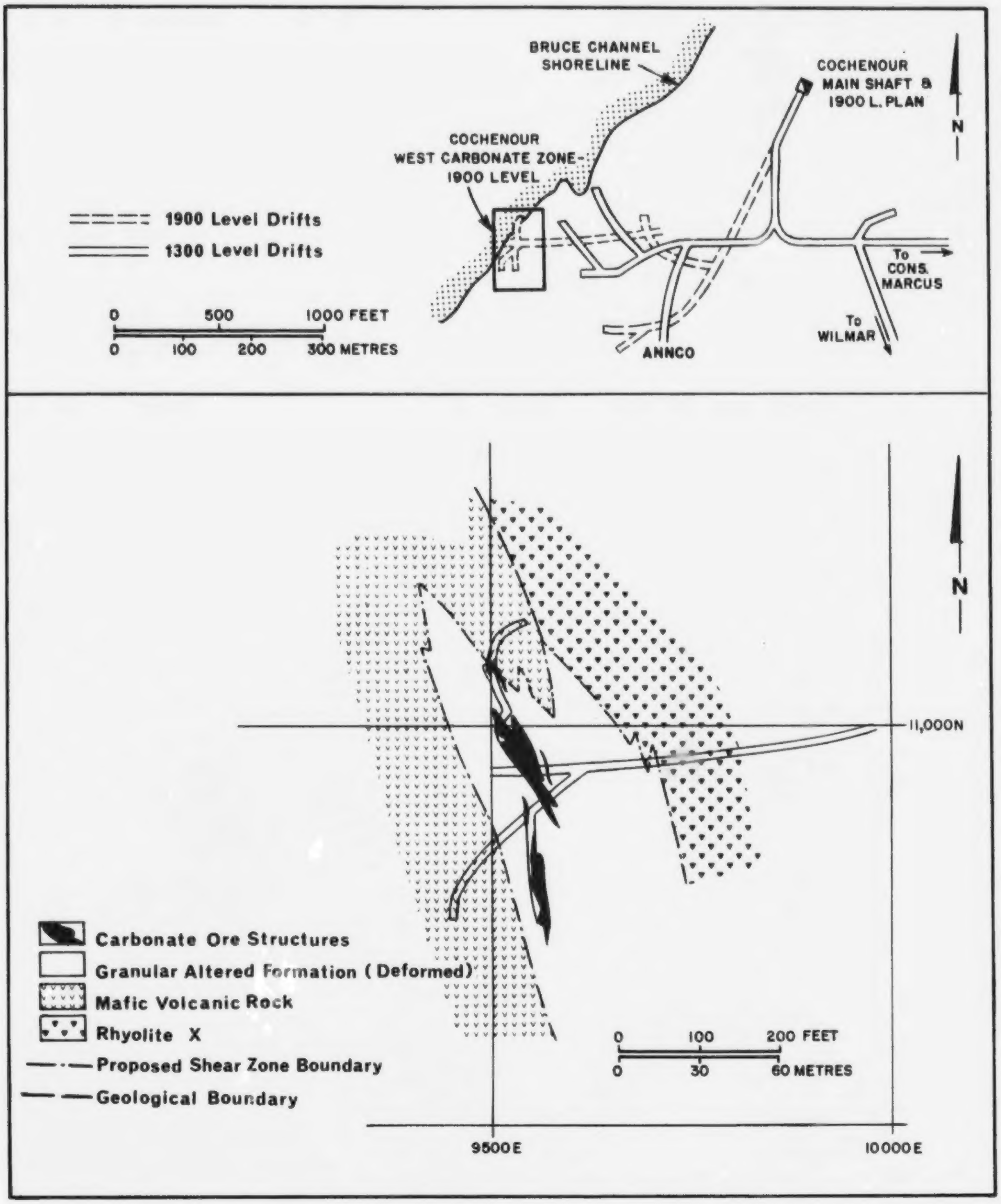
BRUCE CHANNEL SHORELINE
COCHENOUR MAIN SHAFT & 1900 L. PLAN
N
COCHENOUR WEST CARBONATE ZONE-1900 LEVEL
1900 Level Drifts
1300 Level Drifts
0 500 1000 FEET
0 100 200 300 METRES
To CONS. MARCUS
To WILMAR
ANNCO
N
11,000N
Carbonate Ore Structures
Granular Altered Formation (Deformed)
Mafic Volcanic Rock
Rhyolite X
Proposed Shear Zone Boundary
Geological Boundary
0 100 200 FEET
0 30 60 METRES
9500E
10000E

Figure 1. Simplified geology of the West Carbonate Zone, 1900-foot level, Cochenour Willans Gold Mine.

1. foliation trends which increase from a moderately penetrative 120° ± 10° system outside the West Carbonate Zone to a more intense 140° ± 10° system within the zone. Foliation within the West Carbonate Zone frequently exhibits sigmoidal structures characteristic of shear zones, which can be used in this case to suggest a reverse thrust motion on the shear.
2. the presence of abundant stretch lineations on foliation planes, indicative of down-dip extension
3. slickensides, confirming a near down-dip direction of motion and additional evidence of a reverse thrust motion on the shear
4. a significant increase in the frequency of carbonate and quartz veining within the zone
5. well developed examples of pinch-and-swell and boudinage structures in both carbonate and quartz veins indicating a high degree of vertical extension
6. complex, brittle(?) deformation of the large carbonate ore structures, found to dominate the western portion of the shear zone
7. previous surface work, including drilling and detailed ground magnetic and gravity surveys, which supports the presence of a major north-south trending structure in the vicinity of the West Carbonate Zone

Summary

During the 1983 field season, a detailed study was conducted of a portion of the highly complex Cochenour Willans Gold Mine to determine the possible structural controls of mineralization in the area. In conjunction with this field work, laboratory and analytical procedures will now be applied for the purposes of:

1. confirming the existence and detailing the dimensions of a shear zone in the Cochenour West Carbonate Zone
2. ascertaining a direction and sense of movement in the shear zone
3. examining the relationship of the 150° to 170° trending carbonate veins to the zone of deformation. The complex geometry and asymmetrical location of these ore structures towards the western boundary of the zone suggest that they formed prior to shearing and were subsequently deformed as a result of the shear.
4. examining the temporal relationships between gold mineralization and shear deformation. Gold mineralization was observed in both the carbonate material and later, cross-cutting quartz veins.

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No. S51 Structural Studies in Dome and McDonough Townships, Red Lake Area

P. Berger[1] and J.M. Summers[2]

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Introduction

During the 1983 field season, mapping was carried out in the northern part of Dome and southern part of McDonough Townships, an area within the eastern part of the Red Lake "greenstone belt". The area includes the northern half of McKenzie Island, a group of islands to the north and west of McKenzie Island, and the main lake shore extending from the southern end of Post Narrows to the Town of Cochenour. Mapping was carried out at a 1:1000 scale over the whole area and at a 1:10 scale on selected outcrops. The principal aim of the study is to examine the nature, distribution, and significance of deformation structures within supracrustal rocks in order to gain a more complete understanding of the deformation, alteration, and mineralization in the eastern Red Lake area.

The area was first mapped by Horwood (1949), and later by Ferguson (1966) and Pirie (1981). Recent mapping by Wallace (1982) and Andrews and Wallace (1983) was used by them to construct a preliminary model for the general structure of the eastern Red Lake region.

General Geology

The northeastern section of the map area is underlain by a thick accumulation of tholeiitic to komatiitic metavolcanics, metamorphosed at greenschist grade. Bands of iron formation sediments and volcaniclastic rocks of mafic composition ranging in thickness from 2 cm to 10s of metres are found interlayered with both massive and pillowed mafic flows. Iron formation units occur as interlayered sequences of continuous chert and magnetite-rich sediments, and as units made up of sub-rounded to angular, pebble to cobble size clasts of chert, magnetite, and mafic volcanic rocks within an iron-rich matrix. Contacts between dominantly mafic volcaniclastic rocks and iron formation units are gradational.

The mafic sequence is overlain, to the south, by a sequence of reworked felsic tuffs. Outcrops of felsic rocks vary in character from massive, uniform, fine-grained tuffs, composed of quartz and feldspar grains in an aphanitic grey groundmass, to well bedded sequences which, locally, incorporate units composed of up to 50% well rounded, pebble-sized clasts of tuffs, cherts, and mafic volcaniclastic rocks.

Interbedded slate, wacke, and conglomerate sediments crop out on the eastern shore of McKenzie Island, on the Parnell Islands, and on the shore of Slate Bay to the northwest. A late multi-phase intrusion of diorite to granodiorite composition (the McKenzie Island stock) crops out exclusively on the northern arm of McKenzie Island.

Structural Geology

The map area is characterized by significant spatial variations in the intensity of deformation recorded in outcrop and in the degree of development of particular deformation features. Primary bedding within the felsic units and sediments generally dips steeply to vertically. The strike of bedding is 050° to 070° in most outcrops, although local changes in strike occur at mapped fold closures and in zones which may represent fold closures.

Mapping of deformation structures has led to the identification of 3 planar fabrics or cleavages which appear to represent different stages in the deformation history. Each of these planar structures is characterized by a relatively consistent orientation across the whole area, although there are variations in the degree to which any or all of the fabrics can be identified in a given outcrop. Preliminary analysis suggests that the earliest of the 3 fabrics, which trends east-west (090°), represents a plane of flattening normal to the principal shortening direction recorded by deformed pillows, varioles, clasts, and mineral grains. This east-west penetrative fabric may be locally rotated into a more northeasterly trend within layers in bedded tuff and sedimentary units which appear to have acted incompetently relative to adjacent units. The sense of this refraction from competent to incompetent is generally sinistral when viewed on horizontal outcrop. Locally, in thinly bedded outcrops where the 090° fabric is the dominant planar fabric, steeply plunging, tight folds with a symmetric or asymmetric "Z" profile geometry are present. The east-west fabric is axial planar to these structures.

The second planar fabric identified is also steeply dipping and characterized by a regional trend of 050° to 070°. Where this planar structure and the east-west trending fabric are both present in outcrop, the 050° to 070° structure takes the form of a spaced cleavage which appears to displace or rotate the penetrative 090° fabric in a sinistral sense, viewed in a horizontal plane. The significance of this observation and its implications in terms of the relationships between, and relative timing of, the 2 fabric-forming events must await further study of thin sections and analysis of field data. There is a variation in the degree to which the 050° to 070° fabric overprints the 090° penetrative cleavage, both within individual outcrops and between adjacent outcrops. On an outcrop scale, zones of strongly developed 050° to 070° fabric are commonly tabular and steeply dipping. The sense of rotation of the 090° fabric into these zones and the attitude of the internal fabric with respect to the zone boundaries suggest that the 050° to 070° fabric-forming event involved a large component of heterogeneously distributed, possibly transcurrent, simple shear with a movement sense in a northeast-southwest direction. Steeply plunging, tight asymmetric folds with an "S" profile geometry, are locally developed on an outcrop scale about steeply dipping axial planes striking approximately 050° to 070°, and may represent structures formed or re-oriented during this shearing event. Tight folds with the same orientation, developed on an island scale and mapped by tracing iron formation units, may correlate with these minor structures.

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The third fabric or cleavage recognized in the map area trends 120° to 145° and is also steeply dipping. This cleavage locally crenulates the 090° fabric. In well bedded sediments that crop out on the eastern shore of McKenzie Island, this latest cleavage is axial planar to relatively open folds plunging approximately 60° to the northwest. The intensity of this fabric decreases to the north and northwest of the map area. In this region, the effects of the late deformation are difficult to recognize in felsic units but are represented in mafic rocks by metre scale, open folding of an earlier penetrative fabric, and a spaced cleavage which is axial planar to these folds.

Relationships between deformation fabrics are, in many outcrops, difficult to interpret because of alteration involving carbonatization and silicification. Carbonatization, most commonly developed in mafic metavolcanics, is most intense in zones which appear to have suffered the strongest deformation.

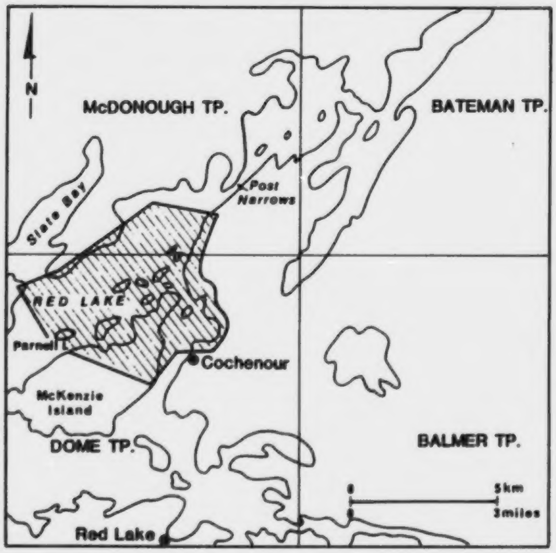

Figure 1. Eastern end of the Red Lake Belt, showing the study area.

Summary

In this contribution, we have described only the most general observations made during the 1983 field season. The relationship between structures developed on a map scale and deformation and alteration features observed on an outcrop scale is as yet unclear and will be the subject of continued study and geometric analysis during the next year. Detailed study of oriented thin sections should clarify the nature and relationships among the various fabric elements discussed. Evidence described for a northeast-directed, sinistral shear deformation event appears to confirm conclusions discussed by Andrews and Wallace (1983) in relation to the structure of the eastern Red Lake Belt in general. The late northwest-trending fabric mapped in our area can be tentatively correlated with a late "fracture cleavage" with the same general trend recognized to the east of our area by Andrews and Wallace (1983).

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No. 52 Applications of Age-dating to Gold Mineralization

Soussan Marmont[1]

Introduction

Subsequent to successful application of geochronology in obtaining age-dates of several units in the Archean stratigraphy, the Mineral Deposits Section of the Ontario Geological Survey has planned a program of age-dating to exploit the available techniques in gaining more information on gold mineralization. It is anticipated that further development of this technique will allow its usage as an exploration tool in search of the precious metal.

In numerous instances, understanding of the evolution of the Archean crust is hampered by inconclusive geological evidence. Clearly, this in turn obscures the comprehension of the spatial and genetic relationships of ore deposits with various geological factors and hence the recognition of the metallogenetic pattern of the Archean terrain. Age-dating of various rock units may offer a definite time frame for each geological event and provide information leading to the answers of some of the problematic concepts. Amongst numerous methods of age-dating which are being practiced and developed, the zircon U-Pb method is considered highly reliable and precise, and is being utilized in the geochronology program of the Ontario Geological Survey.

Some of the zircon age determinations carried out on parts of the "greenstone belts" in the Ontario part of the Superior Province (Pye 1980; Davis and Edwards 1982; Davis *et al.* 1982) have shown that:

1. The stratigraphic time interval of the northern "greenstone belts" is much larger than the more southerly belts. For instance, the North Spirit Lake belt shows a 280 m.y. interval between its first and second cycle of volcanism, the Uchi-Confederation belt shows 165 m.y. between the first and second cycles and 56 m.y. between second and third cycles; an overall time interval of 221 m.y. In contrast, the Abitibi belt shows 22 and 7 m.y. intervals in the Timmins and Kirkland Lake areas respectively.
2. Most of the volcanogenic massive sulphide deposits occur in the later cycles of volcanism and seem to form a cluster in the 40 m.y. time frame between 2740 and 2700 m.y.
3. By abrading the zircons (Krogh 1982a, 1982b) and therefore decreasing the discordancy of the points, a very high precision (of approximately one part per thousand) in the measured age can be obtained.

In the present program, in addition to the zircon U-Pb method, it is planned to utilize other techniques which allow direct dating of ore and/or gangue minerals. Tourmaline, scheelite, rutile, and ilmenite, among others may be suitable candidates for radiometric dating. Use of the ^{40}Ar/^{39}Ar method is also anticipated to yield useful results (D. York, Department of Physics, University of Toronto, personal communication, 1983).

Chronology of the Zircon U-Pb Geochronology Program of the Ontario Geological Survey

The Ontario Geological Survey, in conjunction with the Jack Satterly Geochronology Laboratory, Royal Ontario Museum, Toronto, started a program of age-dating, using the zircon U-Pb method in 1977. The program constituted the dating of felsic and some intermediate (zircon-bearing) volcanic and plutonic rocks of several "greenstone belts" located throughout the Province. These were areas where detailed geological mapping carried out by the Precambrian Section of the Ontario Geological Survey provided a base for geochronology investigation. Preliminary stages of this program, which consisted of the dating of "key units", were designed to yield "absolute" ages in order to clarify and ascertain "relative" stratigraphic relationships and to confirm the reliability of the zircon U-Pb method. This phase of the study was carried out by 1979 and the results were reported in Pye (1980).

The age-dating program in the Western Wabigoon Subprovince (Savant-Crow Lakes area) matured to an advanced stage (Davis and Edwards 1982; Davis *et al.* 1982). In the Uchi-Confederation Lake, Red Lake, Shebandowan, English River, and Mine Centre-Fort Frances areas, the studies are in progress. In the Abitibi area, however, no further work was carried out after 1979.

The Mineral Deposits Section has therefore undertaken an age-dating program to supplement the ongoing studies, through direct application of the method to gold deposits. This program is considered a multi-stage plan, starting with 2 major gold mining camps (the Abitibi and the Red Lake), where reasonable lithological, stratigraphic, and lesser structural information are available.

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Statement of the Problem

Regardless of the specific characteristics of each gold camp or each gold deposit, several geological features are commonly associated with the majority of Archean lode gold deposits. A number of these features can be used in geochronology; these are listed as follows:

1. Heterogeneous host lithology. In some geological settings, one lithology seems to be the dominant host to gold, i.e. felsic porphyries in the Abitibi belt, clastic sediments and iron formations in the Geraldton belt. Nevertheless, in most deposits, almost all "Archean" rock types present in the area may be host to gold mineralization to a greater or lesser extent. In some cases, predominance of one type of host rock (e.g. iron formation) has been considered as an indication of the genesis of the deposit. This aspect is yet to be resolved and there is little conclusive evidence regarding chemical preference of gold for a specific lithology. Dating of "datable" host lithologies, i.e. felsic porphyries and felsic boulders in conglomeratic units, will help in delineating a minimum age for the contained mineralization.
2. Variable stratigraphic position. Unlike many of the volcanogenic massive sulphide deposits which appear to form at the later stages of the younger volcanic cycles, it has not yet been possible to postulate a specific stratigraphic position for most gold deposits. A broad time frame of over 250 m.y. (approximately from 2850 to 2600 m.y.) has been noted for the occurrence of most Archean gold deposits (Woodall 1979). Age-dating of "datable" key units will clarify the sequence of geological events of each belt and therefore bracket the timing of mineralization.
3. Regional to mine scale structural imprints. In the last 2 to 3 decades, the recognition and recording of minor and/or major structural features in ore deposits have been largely ignored and the gap in the application of this aspect of geology to ore deposits is clearly apparent; most data available on various gold occurrences are lithological and/or lithogeochemical and hence the significance or for that matter irrelevance of structural parameters is not considered. In dating pre-, syn-, and post-tectonic and mineralization features, the timing, and hence the association of mineralizing processes with specific tectonic events will be better understood.
4. Alteration processes and metamorphic events, some of which may or may not be directly related to ore forming processes. Dating each event, when possible, will also assist in clarifying the association of gold mineralization with various fluids and their sources.

Present Program of the Ontario Geological Survey

As a basis for further work, a "stratigraphic" dating program is necessary. Where "relative" stratigraphic relationships are obtained through up-dated and detailed mapping, age determination of each "datable" unit should be undertaken. The outcome of this work will result in:

1. obtaining absolute ages for various units
2. verification of stratigraphic interpretation and construction of stratigraphic columns for each "greenstone belt"
3. correlation between belts
4. compilation of enough age-dates that will allow production of a geochronological map of the province

The Precambrian Section of the Ontario Geological Survey is carrying out a co-ordinated program of age-dating and detailed mapping in several parts of Ontario (e.g. Shebandowan, English River, Batchawana). For details of each of these programs, the reader is referred to individual reports in this volume.

For direct application of age-dating to gold deposits, the primary phase of a multi-stage program was carried out as described in the following sections.

The Red Lake Program

In the Red Lake area, detailed mapping (Wallace 1982; Henry Wallace, Geologist, Ontario Geological Survey, Toronto, personal communication, 1983) and study of several aspects of the ore forming processes (e.g. Andrews and Wallace 1983; Durocher 1983) as well as stratigraphic age-dating (F. Corfu, Geochronologist, Royal Ontario Museum, Toronto, Ontario) are in progress.

As part of the continuing studies by A.J. Andrews (this volume), M.E. Durocher and H. Hugon (this volume), and F. Corfu, a sampling program was carried out in August. A total number of 11 samples has been collected, and is listed as follows (numbers correspond to locations on Figure 1):

1. pre-ore quartz diorite, Dickensen Mine
2. post-ore quartz-feldspar porphyry, Dickenson Mine
3. granodiorite, McKenzie Island stock
4. granodiorite, Killala-Baird batholith
5. porphyritic diorite, Howey-Hasaga Occurrence
6. post-ore "felsic" dike, cutting "Austin tuff"
7. "rhyolitic" feldspar porphyry, Campbell Mine
8. trondhjemite, Wilanour granodiorite, Wilmar Mine
9. quartz-feldspar porphyry, Balmer Lake
10. quartz porphyry
11. granodiorite, Abino Stock

For details regarding the selection criteria and discussion of the significance of each sample, the reader is referred to Andrews (this volume).

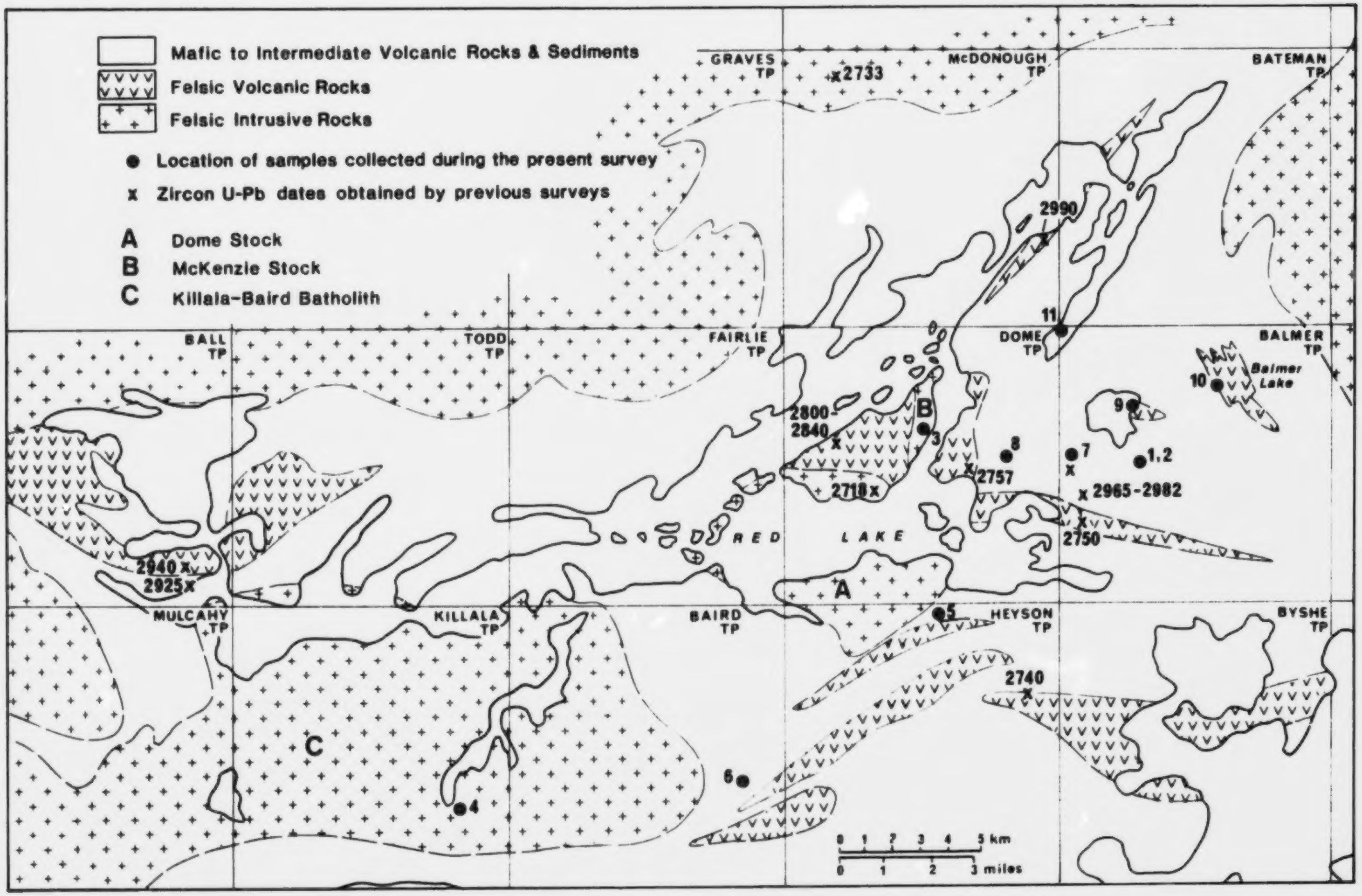

Mafic to Intermediate Volcanic Rocks & Sediments
Felsic Volcanic Rocks
Felsic Intrusive Rocks
● Location of samples collected during the present survey
x Zircon U-Pb dates obtained by previous surveys
A Dome Stock
B McKenzie Stock
C Killala-Baird Batholith
GRAVES TP
McDONOUGH TP
BATEMAN TP
BALL TP
TODD TP
FAIRLIE TP
DOME TP
BALMER TP
Balmer Lake
MULCAHY TP
KILLALA TP
BAIRD TP
HEYSON TP
BYSHE TP
RED LAKE
x2733
2990
11
10
9
8
7
1,2
3
2800-2840
2718 x
2757
x 2965-2982
2750
2940 x
2925 x
A
B
C
5
2740
6
4
0 1 2 3 4 5 km
0 1 2 3 miles

Figure 1. Sample location map of the Red Lake area

The Abitibi Program

Introduction

Several aspects of the geological setting of the Western Abitibi belt, specifically in the Timmins area (the area immediately adjacent to the Destor-Porcupine break) and the Kirkland Lake area (in the immediate vicinity of the Kirkland Lake-Larder Lake break), are subject to controversy amongst the large number of geologists who have studied these areas since the turn of the century.

The geology of the Timmins camp is addressed by Pyke (1982). A calc-alkalic lower cycle (the Deloro Group) and a tholeiitic upper cycle (the Tisdale Group) constitute the volcanic rocks of the area. The Porcupine sediments are presumed time equivalent of the upper Deloro Group and the entire Tisdale Group. All these rocks are intruded by epizonal felsic intrusions which show a distinct localization along the major structures (breaks). Hodgson (1983) presents a new, yet "in large part traditional" hypothesis for the geological history of the area, and compares and contrasts the previous arguments regarding the structural features of the area presented by several other workers such as Pyke (1982), Ferguson *et al.* (1968), and Dunbar (1948). In his study, Hodgson (1983) concluded that the gold mineralizing event had taken place late in the development of the area. It is also emphasized that there is not only an apparent spatial association of gold and "felsic porphyritic units", but also a temporal and therefore genetic link between gold and the "porphyries", and that the localization of the "porphyries" is along major breaks.

Considered on a regional scale, it appears that the known gold deposits of greatest economic significance in the Timmins area are commonly associated with the following features:

1. the Destor-Porcupine Fault
2. carbonatization of the country rocks
3. quartz and/or quartz-feldspar porphyritic intrusive and/or extrusive rocks

It should be emphasized that although there are several occurrences hosted by the various units of the Deloro Group, the best (highest grade and tonnage) deposits are found within the Tisdale Group.

In the Kirkland Lake Camp, Jensen (1979, 1981) has recognized 3 cycles of volcanism consisting of basal komatiitic rocks developing into tholeiitic and calc-alkalic upper portions. Of the oldest cycle, only the upper tuffaceous (Pacaud) unit has been identified in the Kirkland Lake area. The 2 younger cycles are fully preserved and constitute a thick sequence folded about a synclinal (Blake River) axis. The last magmatic event in this area consists of the emplacement of syenitic intrusions and their consanguineous trachytic flows in the Timiskaming metasediments. This alkalic sequence is spatially restricted to the present location of the Kirkland Lake-Larder Lake break; these rocks are the prime host to some of the highest grade gold deposits of the Abitibi belt.

Previous Geochronology in the Abitibi Belt

Three zircon U-Pb dates have been obtained from each of the Timmins and Kirkland Lake Camps by Nunes and Pyke (1980) and Nunes and Jensen (1980), respectively. The particulars of each of these samples are summarized in Table 1. Figure 2 shows the location of the samples.

These data suggest that the upper units in the last volcanic cycles, in both camps, are contemporaneous (2703±2 m.y.), but that the accumulation of the upper cycle in the Kirkland Lake area (approximately 30 km thick) (Jensen 1979, 1981) took place over a much shorter time span (approximately 7 m.y.) than the upper cycle in the Timmins Camp (approximately 22 m.y.).

An unpublished preliminary age-date obtained from the grey, quartz-feldspar Paymaster Porphyry (T. Krogh, Director, Jack Satterly Geochronology Laboratory, Royal Ontario Museum, Toronto, personal communication, 1983) gives an even younger age of 2685 m.y. and suggests a time span of approximately 18 m.y. between the last volcanic event and the emplacement of this porphyritic unit.

Present Survey

In the first year of this multi-stage age-dating program, 5 samples were collected to achieve 2 main objectives:

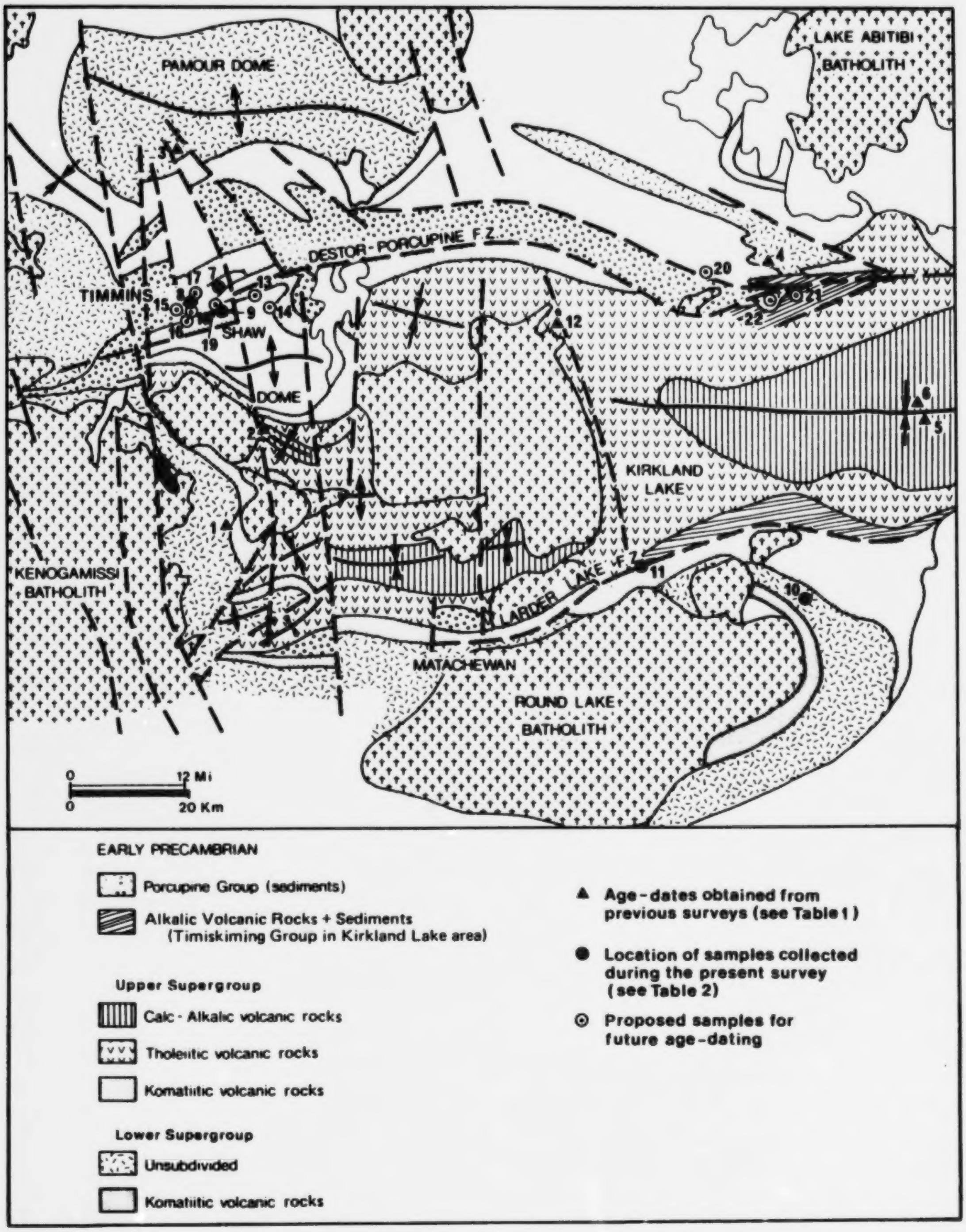
1. to better define some of the stratigraphic relationships extrapolated by various workers
2. to obtain ages for some of the rock units that are host to gold mineralization

It should be emphasised that in using the zircon U-Pb method, the type of "datable" material is restricted to felsic (in rare cases intermediate) and granular (crystalline) rocks. In practice, this will translate into a) rhyolitic to dacitic tuffaceous units constituting the upper portion of a given volcanic cycle, and b) equigranular and/or porphyritic felsic, silica-saturated intrusive rocks. Undersaturated alkalic intrusive material, if potassium-poor, may also contain enough zircon or baddeleyite (ZrO_2) crystals to allow age determination.

Methodology

After checking several surface and underground outcrops for the most representative sample of each unit, approximately 100 to 150 pounds of fresh rocks were collected from each sample site. Care was taken to collect material that was as far from intense alteration and deformation as possible. However, this in an area such as the immediate vicinity of the Destor-Porcupine and the Kirkland Lake-Larder Lake breaks is virtually impossible. The samples collected from the Pearl Lake Porphyry (McIntyre Mine) and the Preston Porphyry (Dome Mine) are highly sheared and fissile, but in relative terms are considered the least altered found in either mine.

The standard laboratory procedures as devised by Krogh and Davis (Royal Ontario Museum) and outlined by


PAMOUR DOME
LAKE ABITIBI BATHOLITH
DESTOR-PORCUPINE F.Z.
TIMMINS
SHAW
DOME
KIRKLAND LAKE
KENOGAMISSI BATHOLITH
LARDER LAKE F.Z.
MATACHEWAN
ROUND LAKE BATHOLITH
0 12 Mi
0 20 Km
1
2
3
4
5
6
7
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17
18
19
20
21
22
EARLY PRECAMBRIAN
Porcupine Group (sediments)
Alkalic Volcanic Rocks + Sediments (Timiskiming Group in Kirkland Lake area)
Upper Supergroup
Calc-Alkalic volcanic rocks
Tholeiitic volcanic rocks
Komatiitic volcanic rocks
Lower Supergroup
Unsubdivided
Komatiitic volcanic rocks
▲ Age-dates obtained from previous surveys (see Table 1)
● Location of samples collected during the present survey (see Table 2)
⊙ Proposed samples for future age-dating

Figure 2. Sample location map of the Timmins-Kirkland Lake area (basemap after Jensen 1981).

TABLE 1 SUMMARY OF ZIRCON U-Pb AGE DATES OBTAINED BY THE ONTARIO GEOLOGICAL SURVEY, IN THE ABITIBI BELT

SAMPLE NO.	AREA, TOWNSHIP	ROCK GROUP (STRATIGRAPHIC POSITION)	ROCK TYPE	AGE IN M.Y.
		TIMMINS CAMP		
1. N-77-16	Bartlett Tp.	upper Lower Supergroup	dacitic, calc-alkalic crystal tuff	2725 ± 2
2. N-77-18	Douglas Tp.	upper Upper Supergroup	rhyolitic, calc-alkalic lapilli-tuff	2703 ± 2
3. N-77-22	Kidd Tp.	upper Lower Supergroup	calc-alkalic, rhyolitic breccia	2708 ± 1
		KIRKLAND LAKE CAMP		
4. N-76-3	Rand Tp.	Hunter Mine Group	dacitic, porphyritic crystal tuff	2710 ± 2
5. N-76-17	Pontiac Tp.	Blake River Group	rhyolitic, quartz-feldspar porphyry	2703 ± 2
6. N-77-12	Pontiac Tp.	Blake River Group	quartz-feldspar porphyry	2703 ± 2

Nunes (1980), and Krogh (1982a, 1982b), will be utilized to treat the collected samples.

Sample Description

Table 2 shows a brief field description of each sample.

Petrographic and geochemical work on these and several other samples taken from the related units are in progress and will supplement the age-dating data.

Future Considerations

A preliminary evaluation of several "datable" rock units was made in the Timmins and Kirkland Lake areas in order to obtain an idea of the existing possibilities. Pending the outcome of the present survey, age-dating of several other rock units will become necessary. The main objectives of further age-dating in the area will be:

1. To distinguish suites of pre-, syn-, and post-deformation/metamorphism felsic intrusive bodies which may show distinct relationships with gold mineralization. In this instance, age-dating of many separate intrusions which are recognizable entities is useful, e.g. Canadian Arrow monzonite (No. 12, Figure 2), Bob's Lake microgranite (No. 13, Figure 2), Mt. Logano granodiorite (No. 14, Figure 2).
2. To ascertain the intrusive or extrusive nature of numerous porphyritic units in the major mines of the Timmins area. Most of the "porphyries" show similar chemistry, morphology, and megascopic petrological similarities, that have made them to be considered contemporaneous. Direct age dating of individual felsic "porphyries" will shed some light on the origin of these units, e.g. Millerton porphyry, Hollinger Mine (No. 15, Figure 2), Crown porphyry, Hollinger Mine (No. 16, Figure 2), Coniaurum porphyry, Coniaurum Mine (No. 17, Figure 2), Acme porphyry, Hollinger Mine (No. 18, Figure 2), Gold Centre porphyry (considered to be equivalent of Krist fragmental), Dome Mine (No. 19, Figure 2).
3. To obtain further stratigraphic age-dates; e.g. the Pacaud tuff (constituting the top of the first cycle of the volcanic rocks in the Kirkland Lake area), the syenite porphyry at the Lake Shore Mine, felsic boulders in the conglomeratic units of the Timiskaming sediments and the Porcupine Group (e.g. Pamour conglomerate).
4. To compare the age of the apparently alkalic suite of rocks occurring at the eastern extremity of the Destor-Porcupine structure with the alkalic suite of rocks in the Kirkland Lake area, e.g. the Michaud Township "monzonite" (No. 20, Figure 2), the Harker Township "syenite" (No. 21, Figure 2), and the Garrison Township monzonite (No. 22, Figure 2). It should be remembered that both suites of rock are host to variable amounts of gold mineralization, the best one hosting the Macassa Mine.

It is hoped that in addition to using the zircon that is found as a rock component, zircon and/or baddeleyite found in mineralized veins hosted by zircon-free rocks (i.e. basalts) could be utilized as a more direct age-dating tool. It is also anticipated that progress will be made in experimenting and directly applying other age-dating methods to gold mineralization.

Acknowledgments

The author would like to express sincere thanks to D. Rogers of Dome Mines Limited for allowing access to the Dome Mine and helping in sampling of the Preston porphyry. P. Walford's arrangement of visits to several of the Pamour Porcupine Mines Limited properties, and A.G. Van Wiecken's aid in obtaining the sample from the Pearl Lake porphyry are greatly appreciated. Thanks are also due to G. Nemcsok of Lac Minerals, Macassa Division, who provided access to facilities at the Macassa Mine.

TABLE 2 **DESCRIPTION OF SAMPLES COLLECTED FOR ZIRCON UPDATING**

SAMPLE NO.		TOWNSHIP	STRATIGRAPHIC POSITION LOCATION	ROCK TYPE
7.	83SM15/TM	Tisdale	Krist fragmental, on the northern limb of the Porcupine Syncline	calc-alkalic, rhyolitic lapilli-tuff
8.	83SM23/TM	Tisdale	Pearl Lake porphyry, McIntyre Mine, 2375-foot level	highly fissile, grey quartz-eye porphyry
9.	83SM32/TM	Tisdale	Preston porphyry, Dome Mine, 1440-foot level	fissile, grey, quartz-eye porphyry
10.	83SM1/KL	Skead	Skead Group, upper part of the second cycle, considered time equivalent of the Hunter Mine Group	calc-alkalic, rhyolitic quartz-eye porphyritic, tuff-breccia
11.	83SM6/KL	Teck	Macassa Mine, 3000-foot level	grey feldspar porphyritic syenite

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No. 53 Current Activities in the Hemlo Area

G.C. Patterson[1]

Introduction

The Hemlo area is located 350 km east of Thunder Bay between Marathon and White River, along Trans-Canada Highway (Route 17). The delineation of a large gold deposit by Teck Corporation Limited (Corona Deposit), Lac Minerals Limited (Williams Option), and Noranda Exploration Limited (Goliath Deposit) has led to a rush to document the geology of the deposits in order to facilitate exploration activities. In addition to company programs, there are 23 research projects being carried out by various universities, the Federal Government, and the Provincial Government (Table 1). This report constitutes a summary of projects known to the author, and also a brief discussion of some of the geological features of this area.

The current projects can be broken down into several groups:

1. Regional Geology

G.M. Siragusa (this volume) is continuing regional mapping to the east of Muir's (1982a, 1982b) map areas. M. Ferreira (University of Western Ontario, London) is doing a regional study of the metamorphic petrology.

2. Local Geology

T.L. Muir (this volume) will do detailed mapping covering the deposit. H. Hugon (University of Toronto) will study the structural geology in the same area. I.P. Cameron (University of Ottawa) and K. Hattori (Geological Survey of Canada) are carrying out isotope studies on the sulphides and sulphates of the deposit. D.C. Harris (Geological Survey of Canada) is carrying out studies on the ore mineralogy.

Detailed studies of the individual sections of the deposit are also being performed:

a) Williams Option (Lac Minerals Limited): R. Barnett is doing a Ph.D. thesis on the Williams Deposit at the University of Western Ontario, London. Three B. Sc. theses are also being done at the University of Western Ontario: P. Neweglowski, Ore Zone Petrology; K. Powell, Hanging Wall Alteration; and P. Trowell, Gold Distribution in the Williams Deposit.

b) Corona Deposit (Teck Corporation Limited): R. Burke (Queen's University) is doing an M.Sc. thesis on the geology of the Corona Deposit.

c) Goliath Deposit (Noranda Exploration Limited): R. Kuhns is doing a Ph.D. thesis at the University of Minnesota on the geology of the Goliath Deposit. T. Hughes (Carleton University) is studying the metamorphic petrology.

3. Exploration Guidelines

a) Geochemistry: John A.C. Fortescue (Fortescue and Geddes, this volume) is carrying out soil and humic geochemistry of the Williams Deposit. P. Friske (Geological Survey of Canada) is doing regional lake bottom sediment sampling. R. Goad (University of Western Ontario) is looking at regional geochemistry for Noranda Exploration Limited. R. Bisque (private consultant) is testing an experimental soil-lithogeochemistry system on the Corona Deposit. F.J. Kristjansson (Ontario Ministry of Natural Resources, Thunder Bay), and R.S. Geddes and G. Jones are carrying out Quaternary geology studies (Fortescue and Geddes, this volume).

b) Geophysics: P. Sivenas (University of Toronto) is testing an experimental S.P. unit on a number of properties in the area.

c) Remote Sensing: S. Yatabe (Waterloo University) is studying the area using Landsat imagery.

General Geology

The area has been mapped by the Ontario Geological Survey. The reader is referred to works by Thomson (1931), Milne (1968), and Muir (1982a, 1982b). This mapping defines an east-trending belt of Early Precambrian (Archean) metasediments and metavolcanics (a part of the Wawa Subprovince) which forms a broad synform. Granitic intrusions occur along the axis of the syncline. The Quetico Gneiss Belt occurs to the north, and the Pukaskwa Gneiss Complex to the south. Muir (1982a, 1982b) divided the belt into 2 main sequences near the Town of Heron Bay. The northern Heron Bay sequence consists predominantly of intermediate to felsic metavolcanics and metasediments. The metavolcanics consist of flows, pyroclastic breccias, and tuffs. The coarsest pyroclastic rocks occur near Heron Bay and gradually become finer grained with a higher component of reworked material (tuffaceous fragments) to the east. Pelitic metasediments begin to interfinger with the tuffs and tuffaceous sediments near Hemlo. Farther to the east, near Struthers, the pelitic metasediments predominate. The southern Playter Harbour sequence consists of mafic pillowed metavolcanics (high-iron tholeiites) which have been intruded by ultramafic sills.

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TABLE 1 CURRENT PROJECTS IN THE HEMLO AREA

University Projects

Researcher(s)	Title*	Affiliation	Discipline
1. R. Kuhns	The Geology of the Goliath Deposit	University of Minnesota	Geology, Ph.D. Thesis
2. R. Goad	Exploration Oriented Geochemistry	University of Western Ontario	Geochemistry, M.Sc. Thesis
3. T. Hughes	Metamorphic Petrology of the Goliath Deposit	Carleton University	Petrology, M.Sc. Thesis
4. P. Sivenas	Self Potential Surveys	University of Toronto Department of Geophysics	Geophysics, Post Doctoral Studies
5. S. Yatabe	Remote Sensing in Hemlo Area	University of Waterloo Department of Geography	Remote Sensing, M.Sc. Thesis
6. R. Burke	Geology of the Corona Deposit	Queen's University	Geology, M.Sc. Thesis
7. M. Ferreira	Metamorphic Petrology of the Hemlo Belt	University of Western Ontario	Petrology Ph.D. Thesis
8. R. Barnett	Geology of the Williams Deposit	University of Western Ontario	Geology, Ph.D. Thesis
9. P. Neweglowski	Ore Zone Petrology, Williams Deposit	University of Western Ontario	Petrology, Ph.D. Thesis
10. K. Powell	Hanging Wall Alteration, Williams Deposit	University of Western Ontario	Alteration, B.Sc. Thesis
11. P. Trowell	Gold Distribution in the Williams Deposit	University of Western Ontario	Geochemistry, B.Sc. Thesis
12. H. Hugon	Deformation and Faulting in the Hemlo Area	University of Toronto	Structure, Post Doctoral

Private Consulting

13. R. Bisque	Experimental Soil-Litho Geochemistry of the Corona Deposit	Private Consultant	Geochemistry

Ontario Government

Worker(s)	Title*	Affiliation	Discipline
14. G. Siragusa	Cedar Lake Area	Ontario Geological Survey Precambrian Section	Regional Mapping
15. T. Muir	Hemlo Camp Area	Ontario Geological Survey Precambrian Section	Detailed Mapping

TABLE 1 CURRENT PROJECTS IN THE HEMLO AREA (continued)

16.	J.A.C. Fortescue	Geochemistry of Humic Layer and Basal Soil on the Williams Ground	Ontario Geological Survey Geophysics/Geochemistry Section	Geochemistry
17.	B. Geddes and G. Jones	Aggregate Inventory of the Hemlo Area	Ontario Geological Survey Engineering and Terrain Section	Quaternary Economic Geology
18.	R. Kristjansson	Quaternary Mapping in Marathon, White River, Manitowadge Town Areas	Ministry of Natural Resources, Thunder Bay	Quaternary Mapping
19.	G.C. Patterson	Regional Metallogeny Including Property Descriptions and Alteration Patterns	Ministry of Natural Resources, Thunder Bay	Economic Geology
		Federal Government		
20.	P. Friske	Geochemistry of Soil and Lake Bottom Sediments in the Hemlo Area	Geological Survey of Canada, Geophysics and Geochemistry Division	Geochemistry
21.	K. Hattori P. Cameron	Isotopic Composition of the Hemlo Deposit	Geological Survey of Canada, Resource Geophysics and Geochemistry Division and University of Ottawa	Geochemistry
22.	D.C. Harris	Ore Zone Mineralogy of the Hemlo Deposit	Geological Survey of Canada, Mineralogy Section	Mineralogy

*Note: Many of these projects are in the preliminary stages and their titles may be changed.

Local Geology

The local geology has been described by the staff of Noranda Exploration Limited (1983), Quartermain *et al.* (1983), and R. Valliant (Exploration Manager, Lac Minerals Limited, personal communication, 1983). A section through the deposit along the Trans-Canada Highway was stripped and mapped and a road guide is in preparation. All rock units strike at 110° and dip 45° to 55°N. The hanging-wall rocks consist of metasediments (siltstones, argillites, pelites, and calc-silicates) with tuffs and lapilli-tuffs (possibly conglomerates also). The main ore zone is hosted in stratiform siliceous sedimentary rocks and/or tuffs that have been highly deformed. The footwall rocks are crystal tuffs and metasediments (wacke and calc-silicates).

Ore Zone Alteration

Preliminary work indicates that the rocks hosting the Hemlo Deposit are strongly altered. The crystal tuff footwall rocks contain tourmaline, green mica, sericite, and hematite. The hanging-wall sedimentary rocks have been silicified and contain epidote and arsenopyrite. Some of the pelitic rocks may have been derived as a result of alteration. A series of core samples were collected from the east and west zones of the Corona Deposit. Detailed petrochemistry and petrography will be carried out on these rocks. One of the main difficulties in dealing with the alteration is the variablility of the hanging-wall rocks. Further sampling will be carried out to define the regional background of the unaltered rocks in order to outline the extent of alteration.

Structural Geology

Some limited work was carried out to more clearly define the structure of the Hemlo Greenstone Belt. The belt appears to be folded about an east-trending fold axis. Rocks to the south of the axis dip north while those to the north dip southward, defining a large scale synform. A number of empirical observations with regards to the structural geology can be made:

1. The clasts in the conglomerates and volcanic breccias show both flattening and lineation. The ratio of the dimensions of the clasts is 1:4:15, where the shortest dimension (1) is perpendicular to the foliation, the intermediate dimension (4) is parallel to foliation and perpendicular to lineation, and the longest dimension (15) is parallel to foliation.

2. Minor folds, which are very common, indicate that foliation is parallel to the axial plane and lineation is parallel to the fold axis. The foliation often occurs at an angle to bedding.
3. The lineation (intersection of bedding and foliation) and axes of the minor folds change systematically through the Hemlo Belt. At White River, the lineation is 45°E; at the Hemlo Deposit it is 70°E, and at the Town of Heron Bay it is 45°W (the strike is consistently east-west).
4. Top indicators such as pillows, flow units, graded bedding, rip-up clasts, and scour channels show many reversals. A similar pattern of reversals is shown in structural top determination measurements (lineation).
5. The lineation-foliation described above has been folded in the area south of the Town of Heron Bay. Air photographs show a large scale fold 4 km across, suggesting a second period of deformation. In outcrops along the access road into Pukaskwa Park, 2 distinct foliations and lineations can be observed as well as refolded folds, implying multi-phase deformation.
6. In relationship to the present siting of mineralization along the contacts between tuffaceous and pelitic units, the question of structural or stratigraphic control of the ore arises. Throughout the belt, the contacts between the brittle tuffs and the ductile pelites are highly deformed. Commonly, the crystal tuff has been converted to a sericite schist which has been highly folded along its contact with the sediment. In thin section, the sericite schist contains quartz phenocrysts that are sheared along the foliation.
7. Cataclastic Rocks and Mylonites: A lineament from Rous Lake to approximately Moose Lake can be followed along the Trans-Canada Highway. A chlorite schist (Hemlo Fault) marks the contact between mafic volcanic rocks to the south and sedimentary rocks to the north. This zone contains tourmaline and fluorite.
8. Kink bands trend approximately north-south. This parallels the trend of major lineaments visible on Landsat photographs and the strike of many diabase dikes.
9. The strike of the feldspar porphyry dikes is parallel to foliation. Where foliation is at an angle to the bedding, the dikes also cut the bedding.

Further work is required to refine the information presented and to interpret the regional structure.

Sedimentology of the Hemlo Belt

Currently, there is no active research being done on regional sedimentology. A number of observations, however, have been made by various workers in the area:

1. On a regional scale, there appears to have been a felsic pile near Heron Bay with pyroclastic breccias that become progressively finer to the east where a source of clastic material is postulated. This is manifested in wackes which show Bouma sequences, rip-up clasts, and scour channels (Muir 1982a, 1982b).
2. A possible unconformity has been identified between the ore zone and overlying sediment. A conglomerate along this contact contains fragments of ore (R.A. Quartermain, Project Geologist, Teck Corporation Limited, personal communication, 1983).
3. A number of sedimentary rock, pelite, and calc-silicate units occur in the belt. These sediments are unusual in the Superior Province and may be related to the mineralizing process.

All of the above observations need to be extensively documented in order to determine the role of sedimentation in mineralization

Summary

Active research is being carried out on most aspects of the geology of the Hemlo Deposit with 2 exceptions: the regional structural geology, and the sedimentology of the area. Studies on these aspects of the deposit need to be undertaken before a complete understanding of the deposits can be made.

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No. S54 Gold Deposits of the Lake of the Woods Area

J.C. Davies[1]

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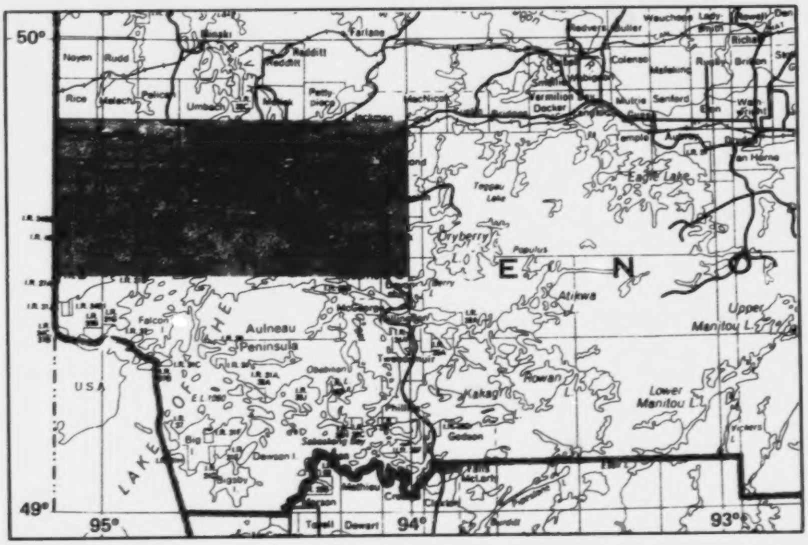
Introduction

The Lake of the Woods gold area was vigorously prospected at the turn of the century. Modest gold production was recorded at that time, and also in the 1930s and 1940s. Exploration has taken place periodically during the past 3 decades in various parts of the area, both for base metals and gold, and many of the old gold properties have been re-examined. Published data from the Consolidated Professor Mining Limited Property on Shoal Lake show reserves of 1.927 million tons grading 0.3 ounce gold per ton (Northern Miner, 7 July, 1983).

A systematic study of the gold occurrences of the area was commenced in May 1983. The 2-year program of field studies and research, funded under a NORDA grant, is designed to provide not only a comprehensive review of the individual occurrences but also an assessment of the lithological, structural, and geochemical factors relating to gold mineralization in a regional context. The study follows a discussion by Blackburn and Janes (1983) of factors which may have been important for gold emplacement in northwestern Ontario.

Metavolcanics underlie most of the Lake of the Woods-Shoal Lake area. While these have apparently been subjected to peak metamorphism of upper greenschist or lower amphibolite facies, pervasive foliation accompanied by significant elongation of primary features is evident in much of the area. In general, a lower and an upper volcanic sequence have been recognized, each consisting of basal mafic flows overlain by intermediate to felsic pyroclastic rocks with some interbedded sedimentary rocks near the top.

Approximately 60% of the known gold occurrences in the area are associated with the lower mafic volcanic rocks and an additional 10% are in granitic rocks near the contact with lower mafic volcanic rocks. These occurrences are principally in 3 areas: the central part of the Shoal



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

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Lake area, the High Lake area, and the Bigstone Bay-Kenora area. It was to these 3 areas that the 1983 field work was directed.

Shoal Lake Area

The geology of the Shoal Lake area has been described by Davies (1978). The principal structural element of the area is a northeast-trending anticline, exposing some 1800 m of fine- to coarse-grained mafic flows (and sills?) which are overlain by about 2100 m of intermediate to felsic flows and pyroclastic rocks. A series of faults striking approximately at right-angles to the lithologic units is evident in the mafic core.

The Canoe Lake stock occupies the anticlinal core to the northeast of Shoal Lake, and consists of quartz diorite together with a variety of finer grained and porphyritic dikes. Although the quartz diorite is typically fractured, chloritized, and saussuritized, the surrounding mafic rocks are mostly fresh looking and lack a planar fabric. It is within 4 km of the stock margin that most of the old gold workings are located. During the summer field season 29 of these were examined. Where in close proximity, 2 or more occurrences may be shown as a single occurrence on Figure 1.

Three principal types of mineralization were recognized, the most important of which is silicification along fault or shear zones which strike between 110° and 155° in basalt. The silicification may be poorly defined, but typically is represented by quartz veins or a system of quartz veinlets which have replaced schistose mafic material within the fracture. Commonly, felsite or granitic porphyry is present in or adjacent to the fractures, and in most places it can be demonstrated that the silicification postdated the intrusion of felsic dikes. Carbonate is also abundant in many of the fracture zones. Sulphide minerals (mostly pyrite) tend to be concentrated at vein edges. This mode of mineralization is found at the former Mikado, Cedar Island, and Olympia Mines, and the Yum Yum, Bullion No. 1, Bullion No. 2, and Imperial Occurrences. Two of the veins on the Gold Coin Property are similar to those described above, but the host rocks are dacitic. Visible gold has been reported at all of these occurrences; at the Mikado Mine it is in hairline fractures near the edges of the quartz veins.

Disseminated sulphide minerals within poorly defined fractures in quartz diorite were apparently the target of work done at the Sirdar and Tycoon Occurrences, and at 2 of the 3 shafts at the Crown Point Occurrence. The presence of felsite at the 2 Sirdar shafts may indicate they were sunk on larger fractures. Typically, few quartz veins are evident, and these contain a maximum of 2% pyrite. The high gold assays recorded in old reports have not been verified, but gold up to 10 parts per million is present along some shear zones in the quartz diorite. Additional observations on mineralization within the Canoe Lake stock have been made by Sutherland and Colvine (1979).

Strike-slip shear zones appear to be relatively unimportant in the vicinity of the Canoe Lake stock. At the Machin Zone, about 2 km west of the Olympia Mine, a sheared felsic rock, probably a dike but possibly a thin pyroclastic bed, has been silicified and contains considerable pyrite. The Gold Coin No. 6 Occurrence vein is a silicified zone in intermediate volcanic rocks. At both Pine Island and Gold Reef Island silicified zones are present in strong narrow shear zones in intrusive diorite.

The most important recent exploration activity has been the drilling of the Cameron Island Property of Consolidated Professor Mines Limited, where several mineralized zones have been identified within an altered, essentially mafic assemblage. The zones had been previously recognized in the underground workings of the former Duport Mine and were thought to be silicified shear zones. The siliceous zones have continuity along strike and down dip and are conformable with contacts of mafic units. It is possible that they are sheared felsic tuffs.

Mineralized zones were also examined near Magnet Point, where quartz and pyrite are present in an altered felsite; at the Great Northwest Occurrence, where minor quartz is present along shears in shear-folded mafic, intermediate, and felsic volcanic rocks; and at the island east of Cash Island, where quartz is present in sheared mafic volcanic rocks of the upper mafic sequence.

High Lake Area

Basalt intruded by granodiorite constitutes a complex zone at the northeastern end of High Lake. On the basis of systematic mapping (Davies 1965), the zone has been interpreted as stoped blocks of basalt enclosed by the granodiorite and related high-level porphyries. Overlying these rocks with marked unconformity are coarse- to fine-grained sedimentary rocks of the Crowduck Lake group.

A number of east-trending faults extend through the area, and the granodiorite to the north and east of the area is fractured, altered, and locally sheared. Silicification and carbonatization accompanied the alteration. In parts of the area pyrite, chalcopyrite, and molybdenite constitute up to 5% of the granodiorite, mostly along minute fractures. Research on some of the mineral occurrences has been carried out by Pedora (1976) and by Sutherland and Colvine (1979).

Gold is present in quartz veinlets in parts of the granodiorite, the distribution being erratic but possibly controlled by shearing. Minor pyrite and traces of chalcopyrite normally accompany the gold. Gold is also present in small amounts (less than 2 grams per tonne) with disseminated and fracture-controlled base-metal sulphide minerals. Gold also occurs, with minor amounts of sulphide minerals, in discontinuous quartz veins and irregular quartz masses in volcanic rocks and sedimentary rocks where these lie adjacent to strong shear zones.

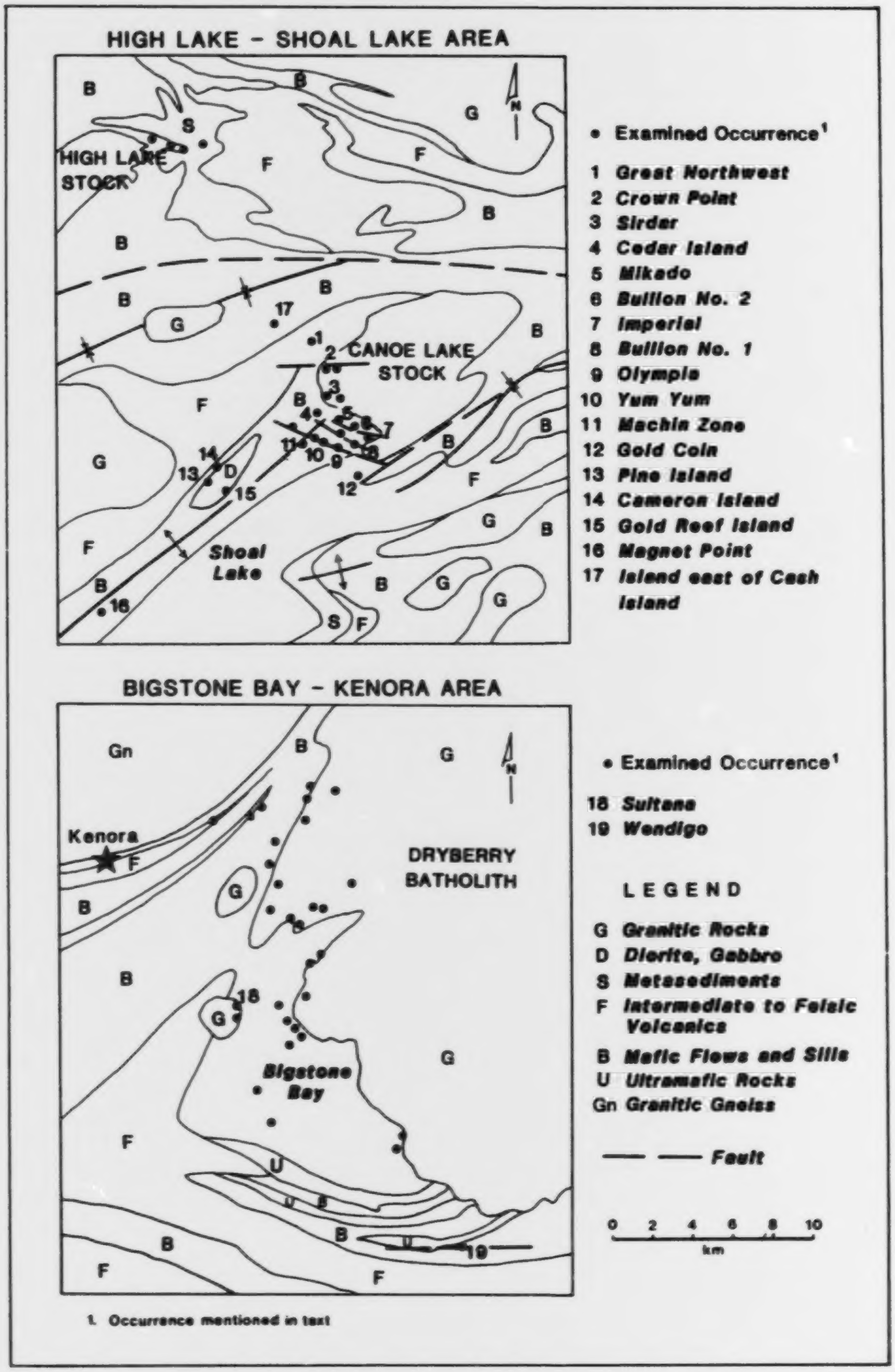
HIGH LAKE - SHOAL LAKE AREA
HIGH LAKE STOCK
CANOE LAKE STOCK
Shoal Lake
• Examined Occurrence¹
1 Great Northwest
2 Crown Point
3 Sirdar
4 Cedar Island
5 Mikado
6 Bullion No. 2
7 Imperial
8 Bullion No. 1
9 Olympia
10 Yum Yum
11 Machin Zone
12 Gold Coin
13 Pine Island
14 Cameron Island
15 Gold Reef Island
16 Magnet Point
17 Island east of Cash Island
BIGSTONE BAY - KENORA AREA
Kenora
DRYBERRY BATHOLITH
Bigstone Bay
• Examined Occurrence¹
18 Sultana
19 Wendigo
LEGEND
G Granitic Rocks
D Diorite, Gabbro
S Metasediments
F Intermediate to Felsic Volcanics
B Mafic Flows and Sills
U Ultramafic Rocks
Gn Granitic Gneiss
Fault
0 2 4 6 8 10
km
1. Occurrence mentioned in text

Figure 1 Geology of the High Lake-Shoal Lake area and Bigstone Bay-Kenora area.

Bigstone Bay-Kenora Area

The rocks of the Bigstone Bay area are essentially massive to pillowed basaltic flows (Suffel 1931) which occupy the core of an east-northeast-trending anticline. Ultramafic flows or sills are exposed on the south limb. The mafic and ultramafic rocks are overlain to the west by intermediate to felsic pyroclastic rocks and are intruded to the east by the Dryberry Lake batholith. To the northwest the basalts link with northeast-trending basalts of the Kenora area.

Regional faults have not been recognized in this area. Virtually all shear zones are parallel to the trend of volcanic lithologies, including those within the adjacent granitic rocks, and almost all of the 30 examined gold occurrences are associated with such shears.

The best developed of these mineralized zones is at the former Wendigo Mine where the host basalt is well foliated over a width of 50 m and where a central zone of more intense deformation is marked by quartz veining. Mine development took place over a strike length of about 200 m where gold in the quartz veins is associated with pyrite and chalcopyrite.

Throughout much of the Bigstone Bay-Kenora area, the gold-bearing silicified shear zones are of the order of 1 m wide. Quartz veins typically pinch and swell where there is demonstrated continuity, but commonly they are irregular or consist of a series of thin veins which individually die out over strike lengths of a few metres. The veins normally contain some carbonate and pyrite, although some veins are essentially devoid of any sulphide mineralization, and black tourmaline is abundant in many of the veins. Visible gold has been reported from most of the examined veins.

The best developed shear zone in granitic rock is at the former Sultana Mine. Most of the outcrop displays a well developed planar fabric and locally the foliation is strong over widths of several metres. Quartz veins do not contain much pyrite but minor pyrite and tourmaline are present in the host rock.

Other Areas

An examination was made of the Little Crowrock Island Occurrence in central Lake of the Woods, where gold is associated with a thin bed of slaty sedimentary rocks; and at the Minerva Occurrence in Poplar Bay, southwest of Kenora, where quartz veins are present in narrow shears in volcanic rocks.

Conclusions

Known gold occurrences in the Lake of the Woods area are associated with shear or fault zones along which there has been silicification, carbonatization, and sulphide mineralization. Tourmaline is commonly associated with the quartz in these zones.

In the Shoal Lake area most gold occurrences are within cross-faults or shears. The Cameron Island gold zones have considerable length, apparently conformable with the volcanic stratigraphy, and may represent mineralized felsic tuff.

At High Lake, major faults have provided some control of the mineralization although, at present, this appears to be erratic.

Virtually all of the mineralization in the Bigstone Bay-Kenora area is along shear zones which parallel the volcanic stratigraphy. Most of these are narrow and of limited strike length.

Recommendations

The extensive gold mineralization associated with carbonatization and silicification in a shear zone cutting pillowed mafic volcanic rocks at the Cameron Lake Property of Nuinsco Resources Limited is an example of the type of deposit which should be sought in the Lake of the Woods area. The zone of deformation associated with the Pipestone-Cameron fault, within which the gold has been found, extends northwestward into the Long Bay fault and probably westward to the Western Peninsula. Carbonatized zones in the Oak Bay and Wiley Bay areas should be examined.

At Shoal Lake the cross-faults in the Helldiver Bay-Bag Bay area coincide with linear depressions and do not appear to have been adequately explored. Also, mineralization of the Cameron Island type may be present along strike or on the southeastern limb of the anticline.

The presence of major faulting and adjacent alteration in the area northeast of High Lake justifies the continued search for gold.

In the Bigstone Bay area the only major shear zone that has been recognized is in the vicinity of the Wendigo Mine. Additional work along the strike of this zone may be worthwhile. In the Kenora area, major shear zones may be concealed by glacial deposits, and geophysical work in this area is warranted.

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LITHOPHILE MINERALIZATION IN ARCHEAN GNEISSIC TERRAINS

No. 55 Granitoid-Associated Mineralization in the English River and Wabigoon Subprovinces near Dryden, Northwestern Ontario

M.E. Cherry[1]

Introduction

Spatial associations between mineralization and granitoid rocks are apparent from examination of geological maps of the Sioux Lookout-Dryden area (Blackburn 1981; Breaks *et al.* 1976; Breaks *et al.* 1978; Page and Christie 1980a, 1980b). Mineralization includes deposits, prospects, and occurrences of gold, molybdenum, tungsten, lithium, cesium, tantalum, and rare earth elements. The genetic significance of the compositionally and texturally complex suite of granitoids to the mineralization is not known, although it is important to evaluation of the mineral potential of the area. A brief reconnaissance of the granitic suite was made and a number of mineral occurrences were visited during the 1983 field season to further assess this association.

Granitoid Rocks

The granitoid rocks of the English River Subprovince have been extensively studied by F.W. Breaks, W.D. Bond, and their co-workers (Breaks *et al.* 1978, and references therein). They defined 3 granitoid suites in the Southern Domain of the English River Subprovince, which underlies much of the Sioux Lookout-Dryden area (Figure 1), based upon their chemical, textural, and tectonic characteristics. These suites are:

1. a gneissic granitoid suite: characterized by layered gneissic textures and including a wide range of lithologies from amphibolite to granite *sensu stricto*. This suite was interpreted by Breaks *et al.* (1978) to be a migmatitic intrusive complex containing supracrustal rocks, and both allochthonous and autochthonous plutonic components. In the Sioux Lookout-Dryden area, most of this suite is of recognizable metasedimentary origin.
2. a sodic plutonic suite: including moderately deformed rocks ranging from trondhjemite to granodiorite, with local quartz monzonite phases. Most occurrences of this suite are foliated and recrystallized; some lack foliation but have been recrystallized to a granular mosaic texture. In the Sioux Lookout-Dryden area, this suite is represented by the Lateral Lake stock, a small plug near Crossecho Lake, the larger Watch Lake stock, and other small intrusive bodies not examined during this reconnaissance.
3. a potassic plutonic suite: dominantly quartz monzonite to granite *sensu stricto* and exhibiting massive, non-recrystallized textures. Grain size ranges from medium to pegmatitic, and is more variable than in the other suites. The potassic suite is the youngest of the 3 granitoid suites. It is represented in the Sioux Lookout-Dryden area by the Gullwing Lake stock, the Basket Lake batholith, and several small stocks intruded into mafic metavolcanics of the Wabigoon Subprovince.

Mineralization

The intent of this reconnaissance was to look for links between mineralization and individual granitoid rock types, as a prelude to possible more extensive study. Brief examinations were made of several occurrences, and the descriptions that follow are correspondingly brief. Readers are directed to the references for more complete descriptions.

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Molybdenum

Molybdenum mineralization occurs within and adjacent to the Lateral Lake stock (Figure 1). The stock and its associated mineralization have been studied by McCarter (1980). The Pidgeon Property, which is the largest and best-known of the molybdenum occurrences (15.8 million tons of 0.08 % molybdenum, McCarter 1980), was visited as a typical example of this mineralization.

The Lateral Lake stock is a foliated granodiorite body, elongate parallel to the regional stratigraphic and structural trends. Shallowly dipping foliation and gneissosity are strongly developed near the margins of the stock, but are weak to absent from the axial area of the stock. These compositional and textural characteristics were used by Breaks *et al.* (1978) to include the stock in the syn-tectonic, sodic plutonic suite.

Molybdenite occurs in and adjacent to granitic aplite veins, quartz veins, and quartz-potassium feldspar pegmatite dikes and sills in foliated biotite granodiorite at the Pidgeon Property. The aplite veins, quartz veins, and pegmatite dikes and sills contain abundant muscovite, which is absent from the Lateral Lake granodiorite, and lack the deformation that has affected the granodiorite. McCarter (1980) suggested that the mineralization resulted from accumulation of residual magma and fluids in a cupola-like upper portion of the Lateral Lake stock as it crystallized.

Rare Element Pegmatites

Granitic pegmatites containing concentrations of lithium, cesium, tantalum, and rare earth elements occur in mafic metavolcanics of the Wabigoon Subprovince in the Sioux Lookout-Dryden area. These pegmatites have been examined by Breaks (Geologist, Ontario Geological Survey, Toronto, personal communication, 1983) and Breaks *et al.* (1978); and by Tantalum Mining Corporation of Canada and Selco Incorporated (Assessment Files, Resident Geologist's Office, Ontario Ministry of Natural Resources, Sioux Lookout). Pegmatites at Tot Lake, Mavis Lake, and Gullwing Lake were visited (Figure 1).

The pegmatites contain variable amounts of quartz, albite, potassium feldspar, and both biotite and muscovite as major phases. Minor phases include spodumene, lepidolite, tourmaline, beryl, garnet, tantalite, cleavelandite, holmquistite, and apatite. Lithophile mineralization in the pegmatites is commonly associated with zones of sodic metasomatism in which potassium feldspar is replaced by low temperature albite. Breaks *et al.* (1978) suggested that these pegmatites were highly fractionated apophyses from muscovite migmatite of the Ghost Lake stock.

Tungsten

Tungsten, as scheelite, occurs in mafic metavolcanics of the Wabigoon Subprovince east of Dryden (Figure 1). The mineralization is hosted by pillow basalt, which is intruded by a tourmaline-biotite-muscovite pegmatitic granite. The mineralized pillow basalt is highly deformed (length:width ≅ 20:1) and is highly tourmalinized. Tourmaline is especially abundant in pillow selvages, although it also occurs as fibrous aggregates in pillow interiors. Scheelite is believed concentrated in sub-horizontal (fracture?) surfaces, and may also be concentrated in the tourmaline-rich pillow selvages. There seems to be a direct correlation between amount of tourmaline and amount of scheelite present.

The pegmatitic granite contains biotite and muscovite, abundant tourmaline, occasional green beryl crystals, and a distinctive blue apatite. The apatite also occurs in the nearby Mavis Lake pegmatite occurrences.

Discussion

Although the reconnaissance nature of this work precludes definite conclusions, it is important to attempt to identify a metal source for such lithophile mineralization within the vast granitoid terrain of the English River Subprovince, and similarly important for lithophile mineralization elsewhere in the Superior Province. The contacts of the Wabigoon and Uchi Subprovinces with the English River Subprovince host a number of lithophile mineral occurrences in Manitoba and northwestern Ontario. These granitic terrains remain very poorly understood, and distinction of "pregnant" from "barren" granites would be invaluable for definition of exploration targets.

McCarter (1980) has suggested that the sodic magma of the Lateral Lake stock was the source of molybdenum mineralization. However, the host aplites and pegmatites are undeformed, and have mineralogical affinity to the younger, potassic Gullwing Lake stock.

Breaks *et al.* (1978) suggested that the rare element pegmatites were derived from the Ghost Lake stock, which they described as a tourmaline-bearing, homogeneous to inhomogeneous muscovite diatexite. Cerny (1982) describes rare element pegmatites as being equally probably derived from a more homogeneous magma, removed from its source region. The Gullwing Lake stock, again, is a possible source of the rare element pegmatites.

It seems likely from the intimate relationship of scheelite and tourmaline that a boron-rich fluid was responsible for the tungsten mineralization. Such a fluid is easily associated with the tourmaline-bearing pegmatitic granite, which in turn is easily associated with nearby pegmatites.

One distinctive association is emerging, although further work is necessary to confirm its importance. All of the mineral occurrences are associated with granitic rocks containing what appears to be primary muscovite, which limits their emplacement to intermediate and deeper levels in the crust.

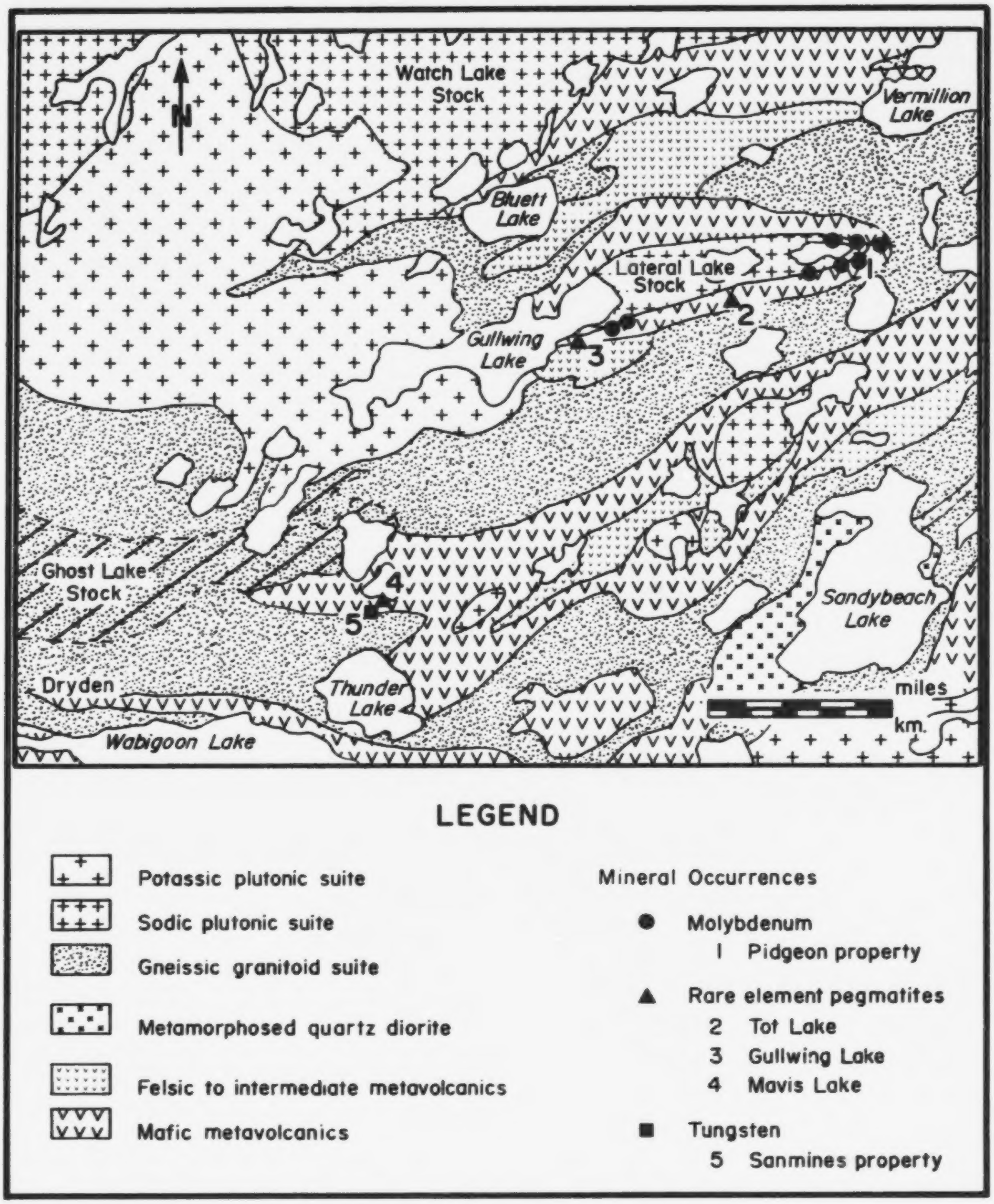
N
Watch Lake Stock
Vermillion Lake
Bluett Lake
Lateral Lake Stock
Gullwing Lake
1
2
3
4
5
Ghost Lake Stock
Dryden
Thunder Lake
Wabigoon Lake
Sandybeach Lake
miles
km.
LEGEND
Potassic plutonic suite
Sodic plutonic suite
Gneissic granitoid suite
Metamorphosed quartz diorite
Felsic to intermediate metavolcanics
Mafic metavolcanics
Mineral Occurrences
Molybdenum
1 Pidgeon property
Rare element pegmatites
2 Tot Lake
3 Gullwing Lake
4 Mavis Lake
Tungsten
5 Sanmines property

Figure 1. Generalized geology of the Sioux Lookout-Dryden area (after Breaks et al. 1978).

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MINERAL DEPOSITS

BASEMENT STUDIES IN THE COBALT AREA

No. 56 Geology of the McLean Lake Area

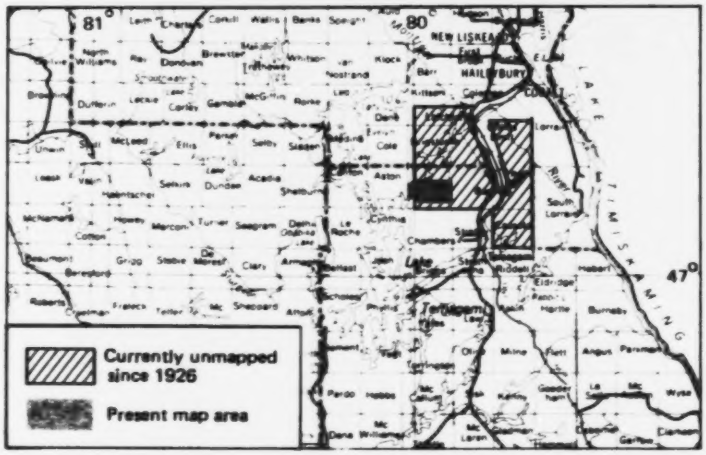
Leo Owsiacki[1]

Introduction

The Cobalt mining camp, discovered and worked since 1903, is well known for its silver-cobalt mines. Vein structures and ores are hosted by diabase, Huronian sediments, and Archean metavolcanics, and show a close affinity to the contacts with Nipissing Diabase sills. Interflow sediments within the volcanic inliers represent one possible metal source for the vein mineralization (Boyle and Dass 1971). The Temagami "greenstone belt", located 35 km to the southwest, includes a number of past- and presently producing mines which extracted iron, copper, nickel, platinoids, and gold. Numerous occurrences of gold and base metals are also widely distributed throughout the belt.

The most recent geological maps including much of the area between the 2 camps were published by Todd (1925, 1926a). The maps are at a reconnaissance scale of 1 inch to 1 mile and show no outcrop locations and little structure. General rock descriptions in an accompanying report (Todd 1926b) identify lithologies similar to those found in Cobalt and Temagami, where extensive mineralization occurs.

Renewed interest in gold is currently being generated by relatively high prices (U.S. $420) and by the discovery of the Hemlo deposits. These deposits are hosted by Archean metasediments and intermediate to felsic tuffaceous rocks (Muir 1982). Todd (1926a, 1926b) included similar descriptions for rocks he found in the Anima-Nipissing Lake area. This project involves, initially, mapping only the volcanic inliers, in detail, within this area (Location Map). One such inlier is situated in central Banting Township. The area is bounded by Latitudes 47°12′N and 47°10′N, and Longitudes 80°01′W and 79°53′W. Extensive sampling of outcrop and follow-up lithogeochemical studies are concurrently being carried out with detailed



LOCATION MAP

Scale: 1: 1 584 000 or 1 inch to 25 miles mapping. An emphasis will be placed on defining gold and base-metal potential in these rocks.

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No assessment work is on file for Banting Township. Prospecting was confined to silver exploration in Nipissing Diabase exposed in the central parts of the township. Ground was held in this area as early as 1929 and was restaked in the period between 1948 and 1951 by Nacso Metals, Michaud and Mrs. Davis, and lastly in 1961 by Rix Athabasca Uranium Mines Limited (Assessment Files, Resident Geologist's Office, Ontario Ministry of Natural Resources, Cobalt). In the past, no attention appears to have been paid to the volcanic rocks exposed nearby.

Progress to Date

Banting Township is readily accessible by a good gravel road leading westward from Highway 11. The road traverses the centre of the map area with further access provided by numerous subsidiary lumber roads and by boat on the many lakes.

Mapping is by pace-and-compass, using air photographs blown-up to a scale of 1 inch to 660 feet for control, and has been completed over the western part of the belt.

The oldest rocks underlying the area are Archean metavolcanics. They are thin bands, characterized by alternating colour and composition. Zones within these banded rocks contain up to 15% green to beige, felsic and epidotized fragments up to 1 mm in length. The fragments are commonly stretched into ellipsoidal shapes or elongated into short lengths which add to the banded appearance of the rock. Many of the bands or beds, commonly 1 cm to 1 m in width, appear to have a tuffaceous origin with beds defined by variations of 10 to 60% fine-grained white feldspar crystals within a chloritic matrix. Todd (1926a, 1926b) described these rocks as "waterlain tuffs". They make up >50% of the volcanic rocks here and range from mafic to felsic in composition. Often, more massive, basic zones are encountered but are not continuous enough to map. In the southern portions of this band, a more mappable tuffaceous unit is present where 10 to 15% stretched and rounded white feldspar fragments or porphyroblasts sit within a massive to banded matrix. A similar unit is described by Todd (1926a, 1926b) in Strathy Township.

More siliceous rocks are exposed in the central parts of the belt. White feldspar crystals (75 to 80%), up to 7 mm in size, and euhedral to subhedral in shape, are set within a foliated, amphibole-rich matrix. This lithology may represent a high-level intrusion or crystal tuff. In this same area, a more pinkish feldspar-rich rock predominates. The feldspars appear to be cataclastically broken down to smaller grains and as such may reflect the sheared contacts of a nearby Algoman granite intrusion.

The tuffaceous rocks have been intruded by a pyroxene porphyry dike in one area but the dominant intrusive body, exposed north and south of the belt, is a medium-grained, pink hornblende granite. The granite is relatively uniform in grain size and is moderately foliated. Hornblende, locally altered to biotite, makes up 1 to 3% of the rock.

A variety of contact features are exposed in areas where the granite intrudes the volcanic rocks. These include:

1. zones of extensive quartz veining, in the granite, within 20 m of the contact. The veins parallel foliation and contain no visible mineralization.
2. zones within the granite and adjacent to the contact which host irregular rafted remnants of the volcanic rocks. These rafts are metamorphosed to amphibolite grade and are characterized by knife-sharp contacts and ragged, irregular, migmatitic shapes.
3. assimilation zones where granite has intruded the volcanic rocks and subsequent partial melting has taken place. The end result is a rock consisting of a mixture of volcanic material and irregular granitic masses which comprise 25% of the total outcrop volume. Granite content increases rapidly inwards and tuffaceous rocks become silicified until the rock takes on the appearance of a fine-grained, banded augen gneiss. The foliation in this zone is very strongly developed by orientation of amphiboles and lineation of quartz and feldspar.

The southern limits of the granite mass have been re-intruded by a white syenodiorite. The contact forms a narrow zone where blocks of the pink granite are incorporated within the syenite. Mineral composition is very variable, with white feldspars predominating (30 to 70%) in a matrix of hornblende (25 to 60%) and muscovite (1 to 3%).

Proterozoic rocks of the Cobalt Group (Huronian Supergroup) unconformably overlie the Archean basement. The sediments belong to the Coleman Member of the Gowganda Formation and outline a northeast-trending paleodepression in the bedrock. The unconformity is exposed in only one location. No change in pebble concentration or compositon within the Huronian conglomerates immediately above the unconformity was apparent. Beds, where present, are gently inclined to the west (0° to 10°) and flow direction is from the northeast. This corresponds to the general strike of the inferred paleodepression.

The most westerly and basal portion of the Gowganda Formation is made up of thick-bedded sands, pebbly sand, and orthoconglomerates. The middle section is composed of thinly laminated siltstones and pebbly wackes with characteristic dropstones and thin (<30 cm), massive sandstone beds. Massive paraconglomerates make up the upper parts of the sequence and are often found capping hilltops.

Nipissing Diabase intrudes all rock types in the eastern map area. It is moderately magnetic and exhibits only the varied texture or pegmatitic phase common to Nipissing sills and dikes. The lack of medium-grained hypersthene diabase is one characteristic of the intrusions identified in

Lundy Township (Owsiacki 1982) as feeder dikes or slightly younger plugs of Nipissing Diabase.

Landsat images including the map area outline a number of major structures, not obvious from aerial photographs. The dominant trends are northwest and northeast but many subsidiary splays at various angles are common. Some of these lineaments have been identified on the ground as chloritic shear zones and faults, with gouge to 20 cm in width. In one instance, an intruded quartz-diabase dike was subsequently sheared and faulted at a much later date.

Only the Early Precambrian rocks show evidence of ductile deformation. Parallel bands of the tuffaceous rocks are locally folded on the microscale. The first and strongest deformational event (D_1) is characterized by isoclinal folding. Both boudinaging of the bands and parting of bands at inflection points are common features. This event is accompanied by development of a strong axial planar schistosity (S_1) which parallels bedding (S_0), trends variably from 58° to 90°, and dips southerly between 67° and 87°. Mineral lineations plunge steeply west. A weak, later fabric manifests itself as small scale crenulations of S_0 and S_1 and a broad warping of the volcanic belt into gentle open folds. The axial trace is roughly 53°.

Later kink bands and faults with minor offsets, striking 326° to 335°, parallel some of the major splay lineaments identified in the area.

The granites and syenites both exhibit moderate to weak foliation. This foliation is produced by parallel orientation of feldspars, hornblende, and biotite. The fabric has a uniformly steep south dip and strikes 045° to 048°. It may, in fact, be associated with the event producing the crenulation described previously.

Within the tuffaceous and more mafic volcanic rocks, mineralization occurs primarily in trace amounts as disseminated pyrite. Occasionally the pyrite is found in concentrations of 0 to 20% in individual beds. In 2 instances, minor amounts of chalcopyrite and sphalerite were identified. Gowganda sediments also commonly contain up to 1% disseminated pyrite. In one area, the pebbly wacke facies was characterized by 1% disseminated flakes of pyrrhotite and chalcopyrite.

Mapping, at this time, is still in its initial stages. More detailed studies of contact relationships and deformational fabrics will be carried out during 1984.

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MINERAL DEPOSITS STUDIES IN THE HURONIAN SUPERGROUP

Introduction by A.C. Colvine[1]

Metallogenetic modeling of the eastern Southern Province of Ontario (Innes and Colvine 1979) highlighted the potential for new styles of mineralization in this important area of historical and current mineral production. In particular, the study indicated a potential for paleoplacer gold mineralization, which has not received serious systematic exploration attention. Numerous projects, requiring integrated mapping, sedimentological and mineral deposits studies, and geophysical and geochemical surveys, were identified; limited resources have permitted only individual components of this original program to be carried out during the last 4 years, with the principal input coming from the Mineral Deposits Section.

The Cobalt Embayment, to the northeast of Sudbury, was identified as an area with potential for paleoplacer gold because "greenstone" sequences to the north were, at least in part, the provenance for the sediments; also, this area is underlain by possibly fluvially deposited units of the Serpent, Mississagi, and Lorrain Formations. Each of these, as well as the Gowganda Formation "channels" to the north of the Embayment, has been the subject of investigation. Wood (1980) conducted a preliminary investigation of residual heavy mineral concentrations in the Bar River Formation, the uppermost formation in the Huronian Supergroup.

Four reports on the Cobalt Embayment are presently being prepared for release as a single publication. The radioactive occurrences in the Wanapitei basin on the southwestern margin of the Embayment (Meyn 1979) were shown to contain sporadic anomalous gold concentrations. In 1981, Long investigated the sedimentology of the Mississagi Formation along the southern margin of the Embayment, including previously known gold occurrences (Long 1981). In 1982, Long investigated the sedimentological framework of the 3 "channels" of Gowganda Formation northwards from the Embayment (Long and Leslie 1982). At least 1 of these has been explored for gold by drilling in recent years, but the sedimentological environment does not appear to be favourable for physical reconcentration of gold in the aqueous depositional system. Reconnaissance work carried out by the author in the Lorrain Formation (Colvine 1981) identified a unit of the Lorrain which appears to be consistently enriched in gold and which may have regional extent; where fairly mature hematitic quartz-pebble conglomerates were located within the hematite orthoquartzite portion of the Formation, anomalous gold values were present in the range of 250 times the background value of 2 parts per billion (ppb) (i.e. 500 ppb), and up to 600 times background (i.e. 1200 ppb). Further investigation of this area has shown much greater structural complexity, including both folding and block faulting, than previously proposed by the author in 1982.

The author believes that, considering the very limited time that has been devoted to this program, the above results strongly support the original hypothesis by demonstrating that gold was present and enriched in fluvially deposited units of this area. Presently reported results from deep drilling northeast of Sudbury have identified anomalous concentrations of gold in the Mississagi and Serpent Formations (Sauerbrei and Phipps 1983). Surficial investigation is hampered by poor outcrop, the tendency for the units with greatest heavy mineral content (pyrite or hematite) to weather out selectively, so that they are less commonly exposed in outcrop, and the possibility of surficial leaching of gold from heavy mineral bearing surface outcrops. Rather than being discouraged by the non-ore grade results to present, the author is strongly encouraged that this is an area of unrealized mineral potential.

During 1983, only limited follow-up work was conducted by the author in the Cobalt Embayment; projects were directed to the area between Sudbury and Sault Ste. Marie, principally in the Lower Huronian formations. Meyer (this volume) is conducting a study of the lowermost Livingstone Creek Formation and the overlying Thessalon Formation, covering all outcrops between Sault Ste. Marie and Elliot Lake. This project was designed to further investigate highly anomalous gold concentrations (up to 4 parts per million (ppm) in pyritic, uraniferous, quartz pebble conglomerate channels in the lowermost Thessalon Formation (G.A. Bennett, Resident Geologist, Ontario Ministry of Natural Resources, Sault Ste. Marie, personal communication, 1982). In this project, Meyer has been considering the possible segregation of uranium and gold in the sedimentary system in comparison to that observed in the Witwatersrand in South Africa, noting the apparent disparity of metal ratios. This work will proceed to full publication during 1984.

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D.G.F. Long has continued his association with the Mineral Deposits Section, focusing his efforts in 1983 on the sedimentary environment and facies changes in the Matinenda Formation between Sudbury and Elliot Lake (Long and Lloyd, this volume). As with Meyer's study, information on gold distribution is not included as analyses are presently in progress.

The author conducted a preliminary investigation of the Lorrain Formation north of Elliot Lake. The relatively thin Lorrain section is well exposed in cliff faces and shows an upwards-cleaning succession similar, although not identical, to that outlined for the Cobalt Embayment; the most hematitic unit is subject to the greatest weathering, exposed only in a few locations at the base of cliff sections, and more commonly forming overburden-covered dip slopes. The stratigraphic sequence has been defined, and the hematitic unit has been well delineated, in previous mapping (Robertson 1977; Wood 1975; Siemiatkowska and Guthrie 1976; Siemiatkowska *et al.* 1976) because of its radioactive nature (thorium-bearing monazite). In some locations, a 30 m thick section of hematitic sandstone was observed. In places this contained quartz pebble channel fillings in which hematite constituted up to 90% of the matrix; in some instances, hematite pebbles were observed, indicative of sedimentary reworking. From the previously discussed metallogenetic model, gold should be anomalously concentrated in this system, but not to high levels because of the dominantly granite provenance. If an analogy can be drawn between this well exposed area and the poorly exposed Lorrain section in the Cobalt Embayment, considerable potential exists for an overburden-covered thicker section of highly gold enriched hematitic sandstones and conglomerates in the latter area.

Two other projects in the Southern Province are nearing completion. Owsiacki is preparing a final map and report on the Lundy Township area west of Cobalt (Owsiacki 1982). In addition to highlighting potential for mineralization in this area, the report will contain a well documented stratigraphic section of the upper Gowganda and lower Lorrain Formations and the transition zone between them. Andrews *et al.* (1982) are involved in a multicomponent study of the geochemistry and alteration around the silver-cobalt vein system at Cobalt and Gowganda. In addition to field and petrographic studies, this project included investigation by several research techniques: oxygen isotopes (R. Kerrich, University of Western Ontario, London); fluid inclusions (D. Strong, Memorial University, St. Johns, Newfoundland); paleomagnetism (W. Morris, Morris Magnetics); and direct dating of ore gangue minerals (D. York, University of Toronto, Toronto). A final report on this project is in preparation for release in 1984.

Further work in the eastern Southern Province will be dependent on the findings of current studies and available resources. It is intended that, at least, the current level of activity will be continued, thoroughly documenting specific aspects of this geologically complex area. Work to date has provided encouragement and partially substantiated the original concepts; a more comprehensive report is currently in preparation by Innes and Colvine, to document the metallogenetic setting of the region encompassing Sudbury, for inclusion in the "Ontario Geological Survey Special Volume on Sudbury" to be released in 1984.

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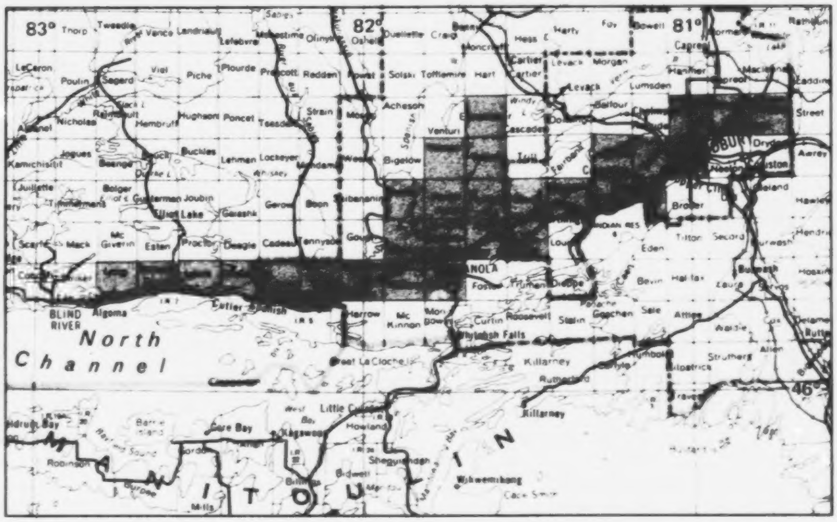
No. 57 Placer Gold Potential of Basal Huronian Strata of the Elliot Lake Group in the Sudbury Area, Ontario

D.G.F. Long[1] and T.R. Lloyd[1]

Introduction

Concentrations of gold have been identified in fluvial conglomerates at the base of the Huronian Supergroup in the area northeast of Sudbury (Long 1981; Long in press) and in related conglomeratic strata in the Elliot Lake Group, associated with volcanic rocks, in the Thessalon area (G.A. Bennett, Resident Geologist, Ontario Ministry of Natural Resources, Sault Ste. Marie, personal communication, 1982). Concentrations of gold in excess of 1 part per million have been found in hematitic quartz-pebble conglomerates and conglomeratic sandstones in the Lorrain Formation in the western part of the Cobalt Plain (Colvine 1982; Long, Leslie, and Colvine 1982). In all of the above cases, the gold is of submicroscopic size and is in fluvial strata in which primary concentration of heavy minerals may have occurred. Examination of non-fluvial strata of the Gowganda Formation in the northern Cobalt Plain (Long and Leslie 1982; Long and Leslie in press)indicates that while some gold enrichment occurs in traction current deposits (to 290 parts per billion), values in excess of 1 part per million are extremely unlikely in subaqueous and subglacial deposits. Long (in press) suggests that gold concentrations in the basal Huronian strata of the Cobalt Plain may be related to diagenetic alteration of detrital magnetite/ilmenite placers by oxidized alkalic groundwaters (Clemmey 1981). In the "Mississagi Formation", magnetite and ilmenite have been replaced by pyrite; in the Lorrain Formation, these common detrital minerals have been replaced by hematite. In both formations feldspars are extensively altered. Again, this may be related to early diagenetic changes related to groundwater movement (Wood 1973; Long 1978).

The present study was designed to test the placer gold potential of the Elliot Lake Group between Long and Falconbridge Townships (Figure 1). The general geology of this area is discussed in papers by Roscoe (1969) and Card (1978) and in numerous detailed geological reports published by the Ontario Geological Survey. Pyritic



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

quartz-pebble conglomerates and conglomeratic sandstones of probable fluvial origin are known in this area both within the Matinenda Formation, and in clastic sediments interbedded with volcanic strata (Robertson 1976). A program of detailed stratigraphic studies, involving observation of bedform sequence and textural variations, was undertaken in conjunction with detailed sampling and paleocurrent analysis (Long 1981; Long in press; Long and Leslie 1982) to provide a basis for future exploration if high gold values are encountered.

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Preliminary Results

Quartz-pebble conglomerates and pebbly sandstones (not always pyritic) were found in close proximity to the base of the Elliot Lake Group in Long, Lewis, Shedden, May, Shakespeare, Baldwin, Hyman, and Drury Townships. Minor quartz-pebble conglomerate is also present in interflow sequences in the Stobie Formation in Garson Township. Conglomerates in strata equivalent to the Matinenda Formation in Falconbridge Township and in interflow sediments in Blezard and Creighton Townships contain only minor quartz pebbles. The irregular distribution of quartz-pebble conglomerates in the western part of the study area can be related to paleotopographic features developed on the Archean basement prior to and during deposition of the Elliot Lake Group. While planar cross stratification is common, at least in the upper 30 m of the Matinenda Formation in the Elliot Lake area (McDowell 1957), it is less prominent south of the Chiblow anticline. Most of the sandstones in the western half of the area investigated are characterized by trough cross stratification, with lesser abundances of ripple cross lamination and plane bedding. The upper part of the Matinenda Formation is interbedded with mudrocks of subaqueous origin which resemble strata in the overlying McKim Formation. Differences in abundance and scale of sedimentary structures north and south of the Chiblow anticline can be related to proximal to distal changes in fluvial style.

Intrusive and extrusive strata of the Salamy Lake Group are interbedded with sandstones, and minor mudstones equivalent to the Matinenda Formation between Victoria and Nairn Townships. Cross stratified sand units become less common to the east, and mudstone becomes more common. In Shakespeare Township, on the southern shore of Agnew Lake, cross stratified fluvial sandstones with minor quartz-pebble conglomerates are present only towards the base of the Elliot Lake Group. Most of the interflow strata in the upper part of the sequence is of deep water origin, representing deposition below wave base in a large lake.

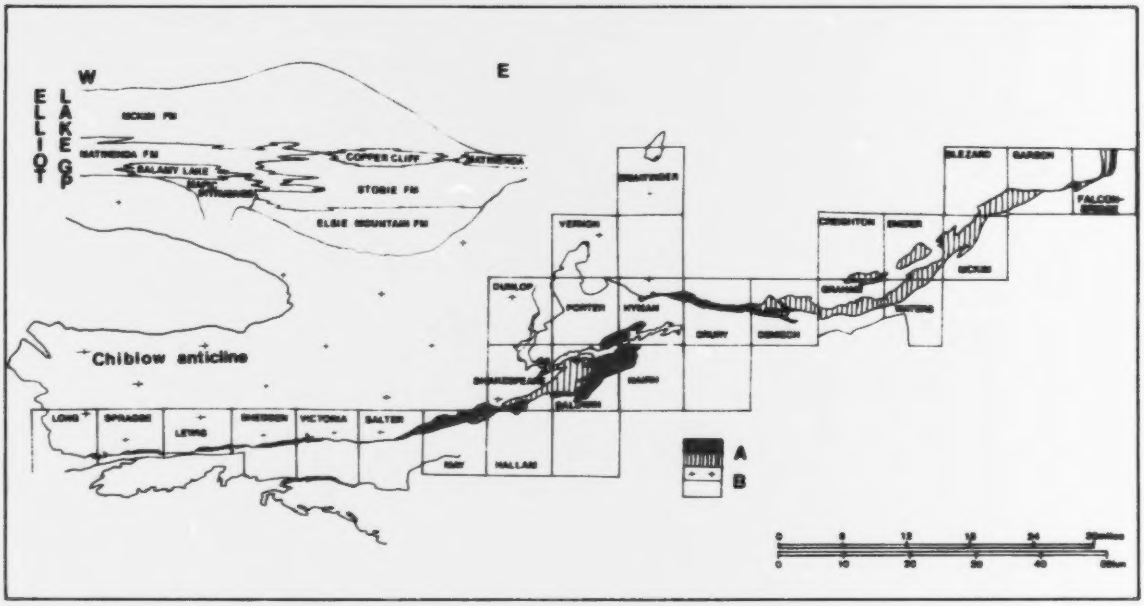
W
E
ELLIOT LAKE GP
McKIM FM
MATINENDA FM
SALAMY LAKE
COPPER CLIFF
MATINENDA
STOBIE FM
ELSIE MOUNTAIN FM
Chiblow anticline
LONG
SPRAGGE
LEWIS
SHEDDEN
VICTORIA
SALTER
MAY
HALLAM
SHAKESPEARE
BALDWIN
DUNLOP
VERNON
PORTER
HYMAN
NAIRN
DRURY
DENISON
CREIGHTON
SNIDER
GRAHAM
WATERS
McKIM
BLEZARD
GARSON
FALCON-BRIDGE
A
B
0 6 12 18 24 30 miles
0 10 20 30 40 50 km

Figure 1. Distribution and stratigraphy of the Elliot Lake Group in the Southern Huronian belt, near Sudbury, Ontario (based on Ontario Geological Survey Maps 2361 and 2419). A = Elliot Lake Group: black = Matinenda Formation; striped = volcanic rocks with interflow sediments. B: + + = pre- and post-Huronian strata; white = younger Huronian strata.

A thin sequence of fluvial strata is present along the northern rim of the Huronian outcrop belt between Vernon and Drury Townships. Most of the sandstones near the base of the Elliot Lake Group in eastern Hyman and Drury Townships are flat laminated, and are interbedded on a large scale with mudrocks resembling the McKim Formation (Card 1965). They are best interpreted as deposits of sediment gravity flows in a deep water, pro-deltaic setting. Interflow strata in the Elsie Mountain, Stobie, and Copper Cliff Formations to the east are predominantly argillaceous (and volcaniclastic) rocks which accumulated in deep water settings below wave base.

Coarse quartzofeldspathic clastic rocks are present in the extreme eastern end of the belt in Garson and Falconbridge Townships, and to a lesser extent in Creighton, Waters, and Blezard Townships, indicating a possible major clastic depocentre fed by rivers from the Cobalt Plain.

Conclusions

No direct conclusions can be drawn with respect to gold distribution until chemical analysis of the 300 samples collected has been completed. The potential for large deposits is low, as coarse fluvial clastics which may have contained placers are comparatively rare and gold distribution may be related to early diagenetic alteration of magnetite/ilmenite placers by acid oxidized groundwater as suggested by Long (in press). The distribution of clastic and volcanic strata in the Elliot Lake Group can be used to support a left lateral strike slip model for initiation of the southern Huronian belt. Volcanism was initiated along a deep crustal fracture, and volcanic rocks are concentrated in the dilation zone of a small pull-apart basin (Crowell 1974). Braided rivers, carrying large volumes of sand derived from Archean granitic terrains, were localized by major trunk streams which ran parallel to the trace of the major faults, forming major deltas at each end of the pull-apart basin. The driving mechanism for the sinistral fault motion may have been oblique plate interaction at a margin several hundred kilometres to the south.

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No. S58 Lower Huronian Gold: An Investigation of Quartz-Clast Conglomerates Between Sault Ste. Marie and Elliot Lake

W. Meyer[1]

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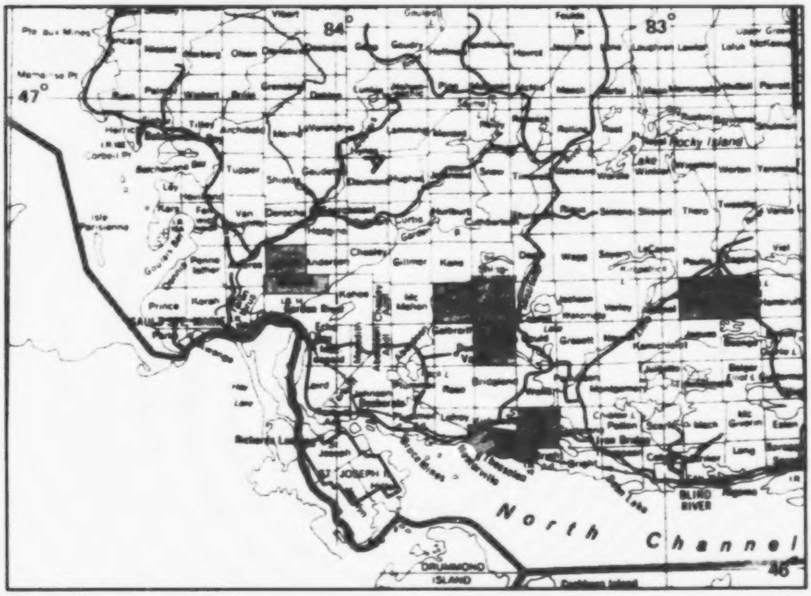
Introduction

Pyritic quartz-clast conglomerates occur in several places east of Sault Ste. Marie at stratigraphically lower levels than the well known uranium-bearing conglomerates at Elliot Lake. Conglomerates crop out in Duncan, Aberdeen, Morin, Otter, Haughton, Thessalon, Day, Nicholas, and Raimbault Townships. Most of the occurrences are easily reached by car and on foot, only those in Raimbault Township require an aeroplane or a canoe trip involving several portages.

In past years exploration of these conglomerates for uranium has identified elevated values but no economic deposits were found. Some of the conglomerates were assayed for gold, but the record of this is rather fragmentary, and the analytical methods do not appear to have been very sensitive; results appear to have been negative. Details of this work are available in the Assessment Files of the Resident Geologist, Ontario Ministry of Natural Resources, Sault Ste. Marie.

The purpose of this investigation is to systematically document the exposed conglomerates and to determine their gold potential, thus complementing work which Colvine (1981), Long (1981), and Long and Leslie (1982) commenced at stratigraphically higher levels in the more easterly areas of the Huronian belt. G.A. Bennett (Resident Geologist, Ontario Ministry of Natural Resources,



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

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Sault Ste. Marie) obtained gold values mostly in the low parts per billion range, but a few as high as the low parts per million range, from samples of several of the conglomerates investigated in this program (unpublished data).

Comparisons have commonly been made between the Huronian Supergroup and the Witwatersrand Supergroup in South Africa, as discussed briefly by Colvine (this volume). Current thinking on the Witwatersrand (Minter 1976; Pretorius 1980) has influenced the approach to this study although it is emphasized that the Huronian is not identical to the Witwatersrand.

General Geology

Roscoe (1969), Robertson (1976), and Frarey (1977) have summarized the geology of the area. The conglomerates of concern lie within or immediately below the Thessalon Formation of the Elliot Lake Group, the lowest of 4 groups within the Huronian Supergroup. Formations within the Elliot Lake Group west of Elliot Lake, in ascending order above the Archean basement, are the Livingstone Creek, Thessalon, and Matinenda. At any one point one or more of these may not be developed. Correlation problems persist, but are not reviewed here.

The Livingstone Creek Formation crops out in Jarvis, Duncan, Aberdeen, Morin, Otter, Haughton, Thessalon, and Day Townships. In Raimbault Township a quartzite-filled crack in the Archean regolith indicates that the formation probably extended this far east prior to deposition of the Thessalon Formation. The Livingstone Creek Formation consists mostly of fine-, medium-, and rarely coarse-grained, parallel-bedded and crossbedded, grey feldspathic sandstones and subwackes. Immediately below the Thessalon Formation the colour is often pink for a few metres.

Oligomictic granite-clast conglomerates commonly occur at or near the base of the Livingstone Creek Formation, but are rare higher in the sequence. Scattered clasts are extremely rare. The clasts are bleached or faintly pink granite, and are clearly derived from the immediately underlying Archean basement regolith. Argillites are rare. The formation varies in thickness from zero to perhaps 350 m, in response to basement topography, but probably also due to early tectonic activity and post-Livingstone Creek erosion.

The Livingstone Creek Formation is rather striking because of its uniform and monotonous appearance over large areas. One might expect the earliest Aphebian sediments of a supergroup, which eventually accumulated to more than 10 km in thickness, to have been much coarser and more varied. The Livingstone Creek Formation is probably a windblown deposit, reworked by flowing water, or alternatively, may represent the distal facies of a once more extensive formation, the coarse proximal facies of which was later reworked and deposited to form stratigraphically higher formations.

The Thessalon Formation consists of mafic and minor acid volcanics, which crop out in several belts west of Elliot Lake, and which accumulated to several hundred metres in thickness. Deep drilling has also confirmed their subsurface presence over large areas. The contact with the Livingstone Creek Formation is sharp, and is probably an erosional break (see below). An erosional break also separates the Thessalon Formation from younger formations such as the Matinenda, Ramsey Lake, and Aweres.

Quartz-clast conglomerates, which occur basal to, or interbedded with, coarse arkoses, are stratigraphically associated with the Thessalon Formation. They are widely distributed, but their extent in any one area is rather restricted. They are best developed near the base of the volcanics, either interbedded with flows in the lower 50 m of the formation, or sandwiched between the lowest flow and the underlying Livingstone Creek Formation. However, they also occur at higher levels. The situation is somewhat different in Morin, Otter, and Haughton Townships, where quartz-clast conglomerates and arkoses overlie fine- to medium-grained feldspathic sandstones which are probably the equivalent of the Livingstone Creek Formation, and which are in turn overlain by a paraconglomerate, not volcanic rocks. Chandler (1973, 1976) has correlated these quartz-clast conglomerates and arkoses with the Matinenda Formation. If he is correct, they cannot be the equivalent of those associated with the Thessalon Formation in the other townships.

Where clast conglomerates and arkoses rest on the Livingstone Creek Formation, they fill channels cut into sandstones, so that the contact represents at least a minor erosional break. Rare quartz pebbles imbedded in the Livingstone Creek Formation, 1 or 2 cm below the contact, suggest that the Livingstone Creek Formation was not fully consolidated when the coarse debris was introduced. Fine-grained quartzites, which are interbedded with quartz-clast conglomerates and arkoses in Day Township and with volcanic rocks in Jarvis Township, suggest local reworking of the Livingstone Creek Formation.

Where conglomerates and arkoses are interbedded with volcanic rocks, the contacts are sharp and irregular. Laterally, the sediments often terminate abruptly against lava.

The greatest measured true thickness of a conglomerate-arkose unit is 14 m, and the longest lateral extent is 152 m, without the strike limits being exposed. Individual conglomerates within conglomerate-arkose units vary in thickness from a single line of pebbles to 2 to 3 m.

Present Investigation

A detailed description of every conglomerate-arkose unit is not within the scope of this summary. The many occurrences were mapped, sampled, and textural and lithological features were noted. A total of 166 samples have been submitted for parts per billion gold and other trace element determinations; 90 to 100 samples are to be cut for either thin or polished thin sections.

Discussion

A discussion without benefit of laboratory results would be premature. The conclusions outlined below may well be revised once more detailed information becomes available.

The quartz-clast conglomerates west of Elliot Lake have a narrow stratigraphic range. They occur either immediately below the Thessalon volcanics, or interbedded with these, mostly within 50 m of the base of the lowest flow.

The close association of the conglomerates and arkoses with the basal Thessalon volcanics suggests that one tectonic event simultaneously triggered an inflow of coarse detritus from outside the basin, and volcanism within. Lava soon choked the sediment supply channels, bringing about the rather limited lateral extent and narrow stratigraphic range. Stratigraphically the conglomerates and arkoses belong to the Thessalon Formation.

Outcropping conglomerates and arkoses can often be seen to pinch out along strike, or become thinner, so that the lensoid shape under overburden can be inferred. The 3-dimensional geometry can only be guessed. Transportation and deposition in channels 20 m to perhaps 200 m wide was the most probable sedimentary environment. No evidence was found to suggest that the conglomerates form areally extensive sheets, as they do at Elliot Lake and in South Africa.

Clasts in most conglomerates are 95% quartz; other components are feldspar, chert, volcanic rocks, and granite. A few conglomerates have up to 40% volcanic clasts. In most conglomerates, clasts are poorly sorted, ranging from granule to cobble, and even to small boulder size. Rounding can be highly variable. Clasts are matrix supported, even if they are densely packed.

The matrix is everywhere a coarse-grained, grey or pink arkose. Occasionally it is green due to chlorite, but this appears to be limited to a few decimetres below a volcanic flow.

Pyrite is common, although its distribution may be very patchy. It generally constitutes less than 1% of the rock as a whole. Pyrite is fine grained, usually less than 0.5 mm in diameter, mostly irregular in shape, but also commonly cubic or dodecahedral, striated, and shiny. It occurs disseminated in the matrix or concentrated on bedding planes, but also smeared on fracture surfaces in quartz clasts. Rounded, dull pyrite similar to Witwatersrand "buckshot" was not seen, but due to possible overgrowth it cannot be ruled out.

Magnetite was not positively identified in the field, although Roscoe (1969) stated that it is present. Magnetite is conspicuously absent from the gold-uranium-bearing conglomerates of the Witwatersrand, the uraniferous conglomerates at Elliot Lake, and similar conglomerates elsewhere. The absence of magnetite from these great ore deposits presents a long-standing dilemma. Being the most abundant accessory mineral in a granite-"greenstone" source terrain, magnetite must have been present in the system. Its selective destruction or transformation to pyrite somewhere between erosion at source and diagenesis after burial may indirectly bear on the origin of gold and uranium, a point commonly passed over in previous research. If magnetite does occur, it should be established whether it is detrital or formed as a result of heat from the lava flows.

Reworking of detritus was minimal, so that the conglomerates are texturally and compositonally rather immature. Conglomerates often grade into pebbly arkoses above and below, and usually the hangingwall and footwall arkoses do not differ from the conglomerate matrix. Bedding is mostly indistinct, and crossbedding is rare. Sharp basal contacts occur only where conglomerates rest unconformably on fine-grained Livingstone Creek quartzites or directly on volcanics. Clearly defined sedimentary cycles, separated by intraformational unconformities with marked lithological changes across these, were not seen. These characterize the Witwatersrand, where texturally and compositionally mature gold-uranium-bearing conglomerates often overlie very immature footwall rocks with marked unconformity.

Economic Considerations

G.A. Bennett's unpublished data indicate that gold was present in the system. It is probably present in scattered detrital grains, so that sporadic enrichment, even to the low parts per million range, will be encountered.

However, lava interfered with the inflow of detritus, so that conglomerates did not coalesce, and sedimentary processes were not able to substantially concentrate heavy metals. It is unlikely that consistent economic grades in adequate volumes of rock to warrant commercially viable extraction were developed in the conglomerates investigated in this program.

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MINERAL DEPOSITS STUDIES IN THE GRENVILLE PROVINCE

Introduction by Janet S. Springer[1]

In the Grenville Province, the Ministry of Natural Resources program of mineral deposits studies is built around a concept of which mineral enterprises could reasonably become viable. This area has both advantages and constraints to mineral development which must be understood if a sensible program is to be developed.

Geographically, the area north of a line through Pembroke and Midland is sparsely populated; south of that line, it is well settled. There is some agriculture and forestry. Both the private sector and the government are making determined efforts to upgrade and intensify the tourist industry. Many tracts are set aside for protection of the natural surroundings.

The historic development of the area means that along the Paleozoic-Precambrian contact about ⅓ of the land is patented, both surface and mineral rights are held privately. Northward, the proportion of lands with rights held by the Crown rises. For the mineral entrepreneur, Crown land makes development easier because negotiation for rights is carried out with only one party. In areas of cottage or retirement properties, there is commonly resistance to development or disturbance.

The Grenville Subprovince has several particular advantages for mineral development. There are good topographic maps, and geological work stretches back over more than a century. The area lies close to consumer industries in southern Ontario and well established transport routes are already in place.

Favourable Mineral Enterprises in the Grenville

The above factors mean that viable enterprises in the Grenville will have a particular profile of characteristics.

They will be small in area. Care will be needed at both the search and development stages, so that disturbance is minimized. If the deposits must be small, economic operations are possible where:

1. a low-value commodity is close to transport, and requires little equipment or skill to recover and no subsequent treatment, or
2. where a commodity has a high final value and can be sold untreated at a low price to a refiner or fabricator, or
3. where the sale value of a commodity can be upgraded by on-site treatment for sophisticated end uses.

Minerals Search

In terms of minerals search this means that methods of extraction and energy use patterns must be borne in mind. The least outlay accompanies materials that are ready concentrated, ground and sorted by geological processes, lie close to the surface, are horizontal, and are close to existing transport.

The end uses of products must be carefully documented to indicate modern trends and market opportunities. For industrial minerals this means that the functional behaviour of the materials must be outlined, because only then can possible substitutes become apparent. More refined uses must be researched for common materials, so that the potential unit earning power may be increased.

Geological Work in the Grenville Subprovince

Work is being carried out by the Ministry's Regional staff in Huntsville, Bancroft, Tweed, and Kemptville, and by staff of the Ontario Geological Survey. Funds come both from the base budget of the Ontario Ministry of Natural Resources and from monies granted for time-bound projects under the Eastern Ontario Subsidiary Agreement. The Federal Department of Regional Economic Expansion (DREE) and Ontario Ministry of Natural Resources contributed equally to this short-term impetus to the minerals program, which is entitled the Southeastern Ontario Geological Survey (SOGS). When SOGS ends in March 1984, the volume of the work will decrease substantially.

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[1] Geologist, Mineral Deposits Section, Ontario Geological Survey, Toronto.

Program Elements

The program areas by commodity are: gold, zinc, graphite, talc, mica, alumino-silicates, and carbonates.

Gold

Regional work by Hans Meyn, Resident Geologist for the Ontario Ministry of Natural Resources at Bancroft, will provide in the next 2 years a modern inventory and some new analyses of gold. D.J. Villard, Resident Geologist at the Huntsville Office, is similarly making inventory and analyses in the Parry Sound area. This will be a basis for examining the setting of gold deposits in the older Ontario Gneiss Segment and of the relationship of gold to stratiform graphite deposits in the area.

At the Tweed Regional Office, P.W. Kingston, Resident Geologist, and V.C. Papertzian are conducting an on-going program of research and examination of gold deposits. A recent report has outlined potential for gold development (Kingston and Papertzian 1982).

At the Ontario Geological Survey, Toronto, E.P. Dillon and P.S. Barron (this volume) are examining the setting of gold veins in the counties of Hastings and Lennox and Addington. This work will form an interesting comparison with the extensive gold studies in other parts of Ontario (Colvine 1983). The documentation of field relationships will provide data for discussion of why many gold occurrences are found close to the basal unconformity of the Flinton Group (Moore 1976; Springer 1982a). Mineralogical work will permit examination of regional mineralogical patterns. Final reports of these studies are expected in mid-1984.

John Malczak has completed a thorough literature search and compilation of records for NTS sheet 31 C, "Kingston", scale 1:250 000. Data include information from Federal, Provincial, and company files, as well as geophysical, assay, and geochemical data for Au, Ag, Cu, Pb, Zn, Mo, and Ni. This is part of the background material for a Geoscience Study (Carter, in preparation).

Zinc

V.C. Papertzian at the Tweed Regional Office is examining zinc deposits. Information on the geochemical relationships of zinc to carbonates and other trace elements in the carbonate rocks has arisen from statistical analyses of data in Papertzian and Kingston (1982a, 1982b). This work is being conducted by W.T. Grant, in Tweed.

Graphite

D.J. Villard and Mary Garland from Huntsville Regional Office are examining graphite-bearing rocks in the Central Gneiss Belt and possible associations of gold with graphite-rich rocks. This work follows studies by Papertzian (1982), (Papertzian and Kingston 1982c), Dillon and Barron (1982), and Springer (1982a, 1982b). Current detailed mapping and sampling have delineated a graphite zone 1000 m long and 100 m wide, with an estimated average grade of 2 to 3% carbon, with concentrations to 30% carbon. Bruno Manella (Prospector, personal communication, 1983) reported a gold value of approximately 1.5 ounces per ton from this property.

Talc

Several reports on talc have been prepared by the Tweed and Kemptville offices (van Haaften *et al* 1980; Young 1982; Verschuren 1982).

The Ontario Geological Survey is continuing its work on talc (Dillon and Barron 1982) in Hastings County and has co-operated with C.P. Verschuren (this volume) in comparative studies on the western margin of the Elzevir granite. A summary of field work (Dillon, this volume) will be followed by a final report in 1984 with discussion of the mineralogy and markets for talc and talc mixtures. Verschuren is also preparing material for 1984 publication.

Mica

Kingston (1982) commented on the potential of mica as a filler. Follow-up work has been conducted in 1983 by C.P. Verschuren and W.T. Grant in the Clare River structure which crosses from Hastings County into Lennox and Addington County. Final reports are being prepared.

Alumino-Silicates

An interest in the alumino-silicate minerals (kyanite, andalusite, sillimanite) has arisen from C.P. Verschuren's work with stratabound mica deposits. He will pursue this interest in 1984.

Carbonates

In the carbonate program, several elements combine to give a rounded study. Regional mapping of sedimentary facies in the carbonate rocks (Bourque 1981, 1982) was conducted in 1981 and 1982. The "Summary of Field Work" for each year is presently available and the final report and maps are in preparation. This work showed that much stratigraphic, sedimentological, and paleontological data (Bourque *et al* 1982) can be obtained from folded, metamorphosed Precambrian rocks. The depositional patterns outlined provide a sound background for the regional sampling of carbonate rocks that was conducted simultaneously in 1981 and 1982. Regional collection of carbonate rocks and subsequent whole rock analysis (Papertzian and Kingston 1982a, 1982b) gave a data base which has now been subject to statistical analysis.

W.T. Grant, in co-operation with staff at Queen's University, Kingston, Ontario, has examined geochemical patterns in this database. The work shows interesting relationships of strontium to calcium, and a lack of correlation between zinc and other elements. Grant has concentrated his field study on the high-calcium marbles. He mapped localities in detail to assess reserves, and examined purity relative to the specifications for filler set by the paint and other consumer industries. He concluded that colour is no indication of purity: grey marbles may be very pure with a silicate content as little as 3 to 5%. A full report will be available in mid-1984.

J.S. Springer has examined high purity magnesian carbonates in Madoc Township. Their end uses as refractories, metallurgical flux, or for the glass industry, means that special attention must be paid to trace levels of boron, sulphur, and phosphorus, and to the Ca:Mg ratio. Overall purity is important. Field studies are found in this volume and will be followed by a full report.

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No. S59 Talc and the Tudor Mafic Metavolcanics, Tudor, Madoc, and Elzevir Townships

E.P. Dillon[1]

THIS PROJECT IS PART OF THE SOUTHEASTERN ONTARIO GEOLOGICAL SURVEY (SOGS) WHICH WAS FUNDED EQUALLY BY THE FEDERAL DEPARTMENT OF REGIONAL ECONOMIC EXPANSION (DREE) AND THE ONTARIO MINISTRY OF NATURAL RESOURCES UNDER THE MINERALS PROGRAM OF THE EASTERN ONTARIO SUBSIDIARY AGREEMENT.

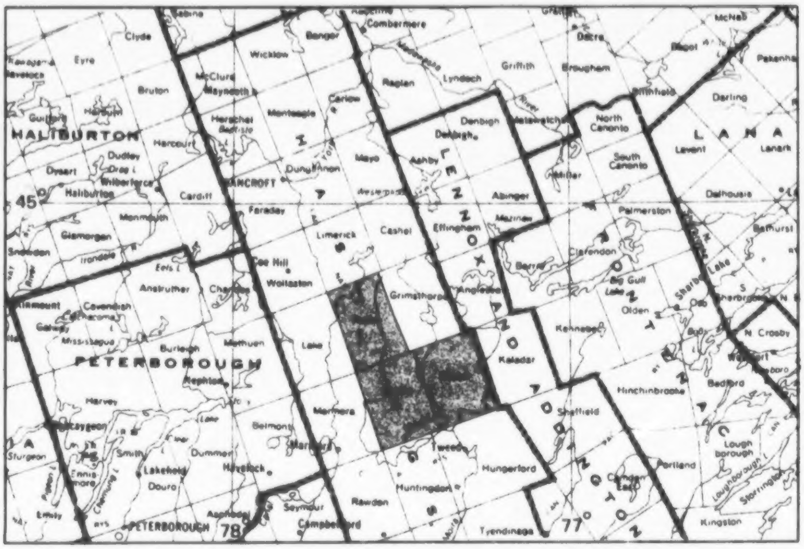
Introduction

Part of the Mineral Deposits Section's component of the Southeastern Ontario Geological Survey (SOGS) Program consists of the study of the geological setting of talc mineralization which occurs in the Tudor metavolcanics within the contact zone and metamorphic aureole of the Elzevir batholith in Madoc and Elzevir Townships (Figure 1). This study consists of 3 parts:

1. the collection of samples from relatively unaltered Tudor metavolcanics in Tudor Township for whole rock analyses and petrographic studies
2. regional (1:10 000 scale) mapping of the contact metamorphic metavolcanics between the Cooper Area Talc Occurrence (Dillon and Barron 1982) and the Queensborough Road Talc Occurrence (Verschuren 1982)
3. detailed (1:2000 scale) mapping of a 500 m^2 area within the Elzevir batholith which consists of a zone of highly altered metavolcanics and talc bodies at the margin of the granite

Talc bodies of significant size (200 to 500 m by 50 to 100 m) and of significant but variable grades (50 to 80% talc) have been outlined, particularly in the Queensborough detailed study area. Although no production has occurred from any of the talc bodies outlined, their significant size and grade makes this a prime talc exploration area worthy of serious economic consideration.

The following descriptions are based on field observations and will be refined when all whole rock, petrographic, and mineralogical studies have been completed.


HALIBURTON
PETERBOROUGH
LANARK
LENNOX AND ADDINGTON
FRONTENAC
HASTINGS
BANCROFT
45
78
77
Sabine
Clyde
Eyre
Bruton
Guilford
Harburn
Dudley
Dysart
Harcourt
Haliburton
Glamorgan
Monmouth
Snowdon
Cardiff
Wicklow
Bangor
McClure
Herschel
Monteagle
Carlow
Mayo
Dungannon
Faraday
Limerick
Cashel
Combermere
Raglan
Lyndoch
Griffith
Brougham
Denbigh
Ashby
Abinger
Effingham
Grimsthorpe
Anglesea
Kaladar
Cavendish
Anstruther
Chandos
Wollaston
Burleigh
Methuen
Lake
Harvey
Marmora
Belmont
Dummer
Smith
Douro
Ennismore
Emily
Seymour
Rawdon
Huntingdon
Tweed
Hungerford
Sheffield
Tyendinaga
Kennebec
Olden
Hinchinbrooke
Bedford
Portland
Kingston
Loughborough
Storrington
Palmerston
Clarendon
Barrie
Dalhousie
Bathurst
Lavant
Darling
North Canonto
South Canonto
Miller
Pakenham
McNab
Bagot
Blithfield
Campbellford
Kingston

LOCATION MAP   Scale: 1:1 584 000 or 1 inch to 25 miles

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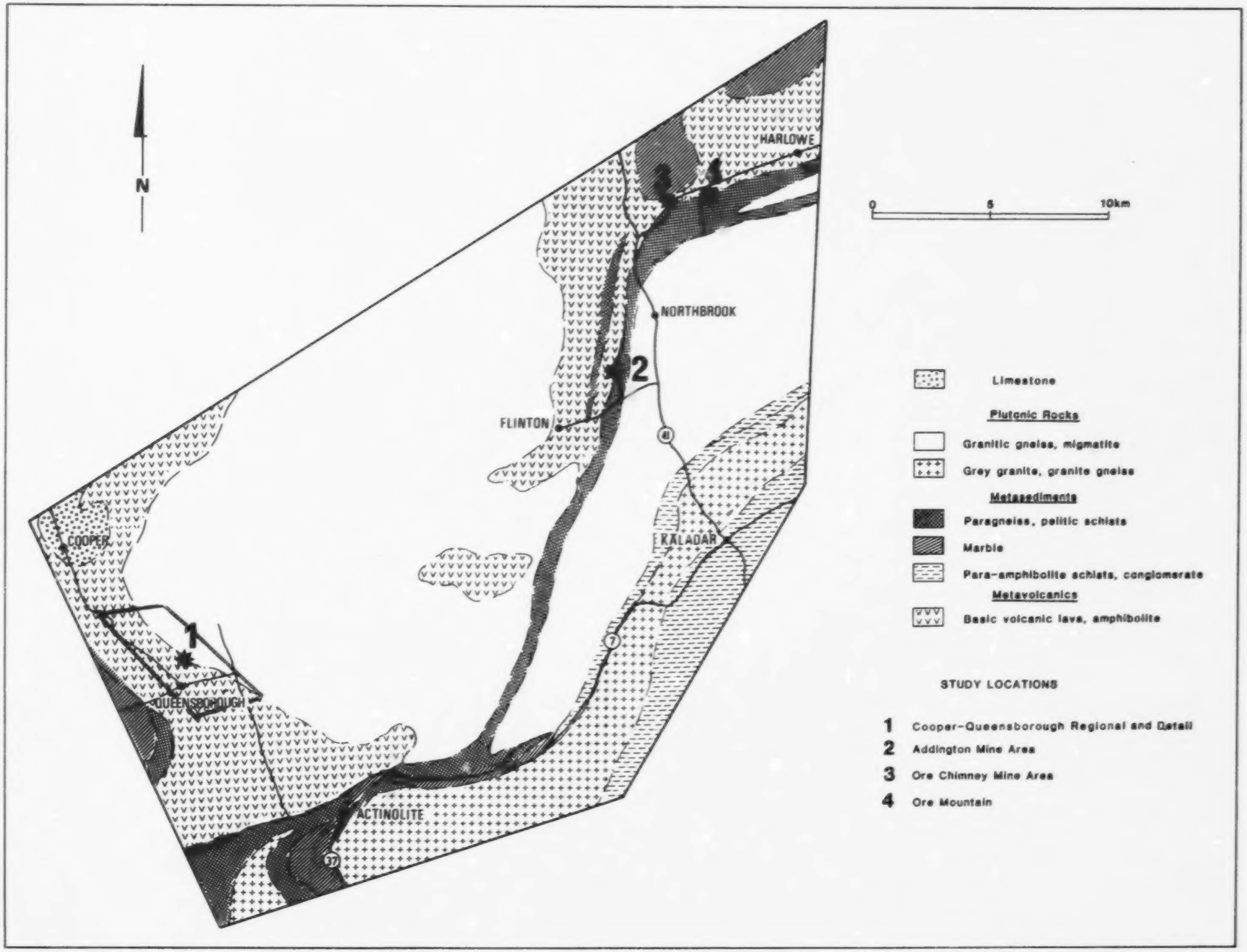
N
HARLOWE
NORTHBROOK
FLINTON
2
41
KALADAR
COOPER
1
QUEENSBOROUGH
7
ACTINOLITE
37
0
5
10km
Limestone
Plutonic Rocks
Granitic gneiss, migmatite
Grey granite, granite gneiss
Metasediments
Paragneiss, pelitic schists
Marble
Para-amphibolite schists, conglomerate
Metavolcanics
Basic volcanic lava, amphibolite
STUDY LOCATIONS
1 Cooper–Queensborough Regional and Detail
2 Addington Mine Area
3 Ore Chimney Mine Area
4 Ore Mountain

Figure 1. Generalized geology and study locations.

Tudor Township Reconnaissance

A total of 18 bedrock localities of Tudor mafic metavolcanics were sampled during 2 days of reconnaissance of highway and bush road traverses in Tudor Township. Lithogeochemical and petrographic data from these samples of relatively unaltered mafic metavolcanics will be used as background data for comparison with similar data from altered Tudor mafic metavolcanics collected in the talc-hosting mafic metavolcanics within the contact aureole of the Elzevir batholith. Samples were collected in areas within the metavolcanics as far from the effects of local intrusive activity as possible.

Within Tudor Township the mafic metavolcanics are fine to medium grained, medium to dark green to black, massive to poorly foliated, and amphibole rich. Foliation is best developed in the fine-grained units and is indicated by crude lineation of amphibole grains in the medium-grained rocks. Primary volcanic textures such as pillows and feldspar (plagioclase) phenocrysts have been preserved within the units sampled, attesting to the relative lack of metamorphic/metasomatic alteration of these flow rocks.

Prior to analysis, a select suite of these rocks will be trimmed of all visible weathered material and halved. One half will undergo whole rock and trace element analysis, the other will be cut for thin section study.

Cooper-Queensborough Regional Talc Study

The Cooper-Queensborough study area is located in east-central Madoc and west-central Elzevir Townships, approximately 11 km northwest of the Village of Tweed (Figure 1). Access to the area is via Hastings Road 20, which runs north off Highway 7 approximately 3 km west of the junction of Highway 37 (to Tweed) and Highway 7 (NTS 31 C/11).

General Geology

In general, the survey area lies within the central metasedimentary belt of the Grenville structural province of southeastern Ontario (Wynne-Edwards 1972). The mafic metavolcanics of the Tudor Formation lie at the stratigraphic base of the Hermon Group, which is the lowest member of the Grenville Supergroup (Lumbers 1964, 1980). The felsic intrusive rocks of the Elzevir batholith intruded the Tudor metavolcanics forming a contact metamorphic aureole within the volcanic rocks bordering the intrusive. The present map area is located well within this contact metamorphic zone.

Description of Units

The mafic metavolcanics mapped during the 1983 field study can be subdivided into 3 broad textural varieties:

1a—amphibolite

1b—chlorite-amphibole schist

1c—amphibole schist

However, due to the often irregular interbanding of these textural types, it was difficult to delineate mappable units within the metavolcanic sequence.

Unit 1a, amphibolite, consists of a medium- to fine-grained, massive to poorly foliated, dark green-grey to black metavolcanic flow rock. Thin, discontinuous zones of medium-grained feldspar-porphyritic amphibolite, fine-grained pyritic amphibolite, and rare pyroclastic material (lapilli-tuff to agglomerate) were encountered during the field investigations. In one area, a 1 m thick conformable medium- to coarse-grained gabbroic amphibolite was located. A narrow horizon of fine-grained, well laminated garnetiferous material is thought to represent a mafic interflow sedimentary unit within the volcanic pile. This unit was encountered mostly along the western margin of the map area with minor zones intermixed with the schistose varieties farther east.

Unit 1b, chlorite-amphibolite schist, is a fine-grained, medium to dark green, well foliated to schistose mafic unit. It occurs intermixed with unit 1c in discontinuous zones 0.25 to 3 m wide and is often developed within unit 1c near the contacts with talc zones. This unit commonly contains minor amounts of talc and may represent a preliminary alteration stage between amphibolite and talcose rock.

Unit 1c, amphibole schist, consists of a medium- to coarse-grained, medium to light green and buff, well foliated and mottled mafic metavolcanic. The mottled appearance is the result of a variable segregation of mafic and felsic components of the rock into 1 to 5 cm discontinuous and irregular lenses and clumps roughly parallel to the regional foliation direction.

The Elzevir Batholith

The felsic intrusive rocks of the Elzevir batholith consist of medium-grained, light to buff-grey, biotitic granodiorite gneiss. Infrequent porphyritic feldspar and quartz-feldspar zones occur but these cannot be mapped as separate continuous phases of the intrusion. Biotite comprises up to 10% of these rocks and it is usually segregated into continuous fine (6.5 to 1 mm) gneissic laminae.

These rocks show typical massive weathering and blocky jointing; no zones were found to be worthy of stone quarrying.

Economic Geology

Talcose zones varying from 8 to 50 m long and 0.5 to 20 m wide are concentrated along the contact between the Elzevir batholith to the east and the Tudor mafic metavolcanics to the west. Minor small discontinuous zones occur along the western edge of the study area within the metavolcanic pile. The talc rocks are fine to medium grained, medium to buff-grey, to pinkish grey, very soft, and have a knobby irregular medium to dark grey weathered surface. These rocks can best be termed as talc-chlorite-magnetite-carbonate schists.

Based on field observations, talc content can vary from 30 to 80% both from zone to zone and within individual zones. Magnetite content can vary from a trace to 5% and occurs as 0.5 to 1 mm disseminated grains. Carbonate is a consistent component of the talc zones and occurs as fine fracture fillings and occasionally as discrete disseminated grain aggregates (0.25 to 1 mm).

In the eastern part of the survey area, within a predominantly intrusive terrain, a broad zone of high grade (50 to 75%) talc mineralization was located (C.R. Young, Havelock, personal communication, 1983). This 500 by 500 m zone was mapped in detail using a 50 by 50 m grid.

Queensborough Detailed Study Area

The Queensborough detailed study area is located approximately 2.5 km northeast of Queensborough and is accessible via a concession road which runs north from Hastings Road 20, approximately 2 km east of Queensborough (Figure 1) (NTS 31 C/11).

Detailed Geology

In this area a zone of highly altered and talcose mafic rocks appears to lie in an embayment on the western fringe of the Elzevir batholith.

The mafic metavolcanics exposed in this area show severe textural variations, probably as a result of intense concentrated contact metamorphic and metasomatic processes. These varieties include:

1c—amphibole schist

1d—amphibolite

1e—chlorite-magnetite schist

1f—talc-chlorite-carbonate-magnetite schist

Unit 1c, amphibole schist, is identical to that described in the previous section of this report and will not be discussed further.

Unit 1d, amphibolite, is a fine-grained, dark green-grey, massive amphibolite which occasionally exhibits poorly developed segregation of mafic and felsic phases into a gneissic or banded amphibolite. Gneissosity is best developed near the intrusive contact with the Elzevir batholith. Magnetite and minor pyrite are common accessories within the unit and both occur as discrete disseminated grains less than 1 mm in diameter.

Unit 1e, chlorite-magnetite schist, is fine grained, light pinkish green, and well foliated. It always occurs bordering talcose zones. Carbonate, in the form of fine fracture fillings, occurs throughout this unit. Infrequent fracture zones occur within this unit and these fractures are usually healed with coarse platy talc. Fractures up to 5 cm wide have been documented but the norm would be 5 to 10 mm. These rocks appear to be an intermediate alteration stage between amphibolite and talc rock.

Unit 1f, talc rock, is medium to coarse grained, medium to light green to pinkish grey, very soft, and exhibits a medium grey to pinkish pitted weathered surface. This unit is well foliated to schistose in character and occasionally shows complex minor folding. Fine disseminated pods of carbonate comprise the principal accessories within these talc-chlorite rocks. Talc content varies from 30 to 80% within the talc zones and averages approximately 60% based on field observations.

The felsic intrusive rocks (units) of the Elzevir batholith consist of a medium-grained, light grey to buff pinkish grey, biotite granodioritic orthogneiss. Biotite content varies from 1 to 3% within these rocks and is often segregated into 1 to 2 mm gneissic bands. These rocks are very consistent in composition with only slight variations in K-spar content. Occasional fine-grained, buff-grey, conformable, aplitic phases of this unit were observed in the more extensive exposures of intrusive rocks in the western part of the study area.

Structural Geology

Throughout the detailed study area, the regional foliation direction varies from 120° to 160°, with dips of 30° to 55° to the west. The foliation within the mafic units parallels the contact with the intrusions. Occasionally local areas of minor drag folding and shearing occur within the talc rich zones. Occasional quartz veining occurs within both mafic volcanic and felsic intrusive units. These veins rarely exceed 10 cm in width, are barren, trend 040° to 090°, and dip 30° to 50° south.

Economic Geology

The talc zones exposed in the Queensborough detailed study area comprise approximately 60% of the area mapped. Outside the detailed study area exposure is limited. However, talcose outcrops have been mapped north, south, and west of the 500 by 500 m grid. This indicates the presence of even more extensive mineralized areas than have been mapped in detail.

Talc occurs as schistose mats of 1 to 2 mm platy grains and makes up 40 to 80% of these rocks. Chlorite, magnetite, and calcite comprise the remainder of these rocks. Further mineralogical and petrographic studies will help determine the physical interrelationships of the mineral constituents of the talcose zones and hopefully provide more detailed data on talc grades.

Within the talcose units and the less altered chlorite-rich unit, magnetite is a pervasive accessory. The unaltered mafic metavolcanics and the felsic intrusive rocks are devoid of magnetite, thus a ground magnetometer would be a useful exploration tool in this area.

Summary

Geological observations within the Cooper-Queensborough area indicate the presence of an extensive belt of altered, talcose rocks within the contact metamorphic aureole west of the Elzevir granodiorite batholith. Mapping in the Queensborough detailed study area indicates the possibility of large areas of talc mineralization exposed on surface and readily accessible.

Land holdings within this region include both Crown land and privately owned patented lots, thus the acquisition of favourable areas will require staking and option agreements.

Further detailed work is required to fully determine the economic merit of the talc mineralization occurring in this area. Detailed drilling and bulk sampling of the more favourable mineralized zones would be required to provide much needed information on the beneficiation of, and grade variations within these talc bodies.

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No. S60 Gold-Arsenopyrite-Quartz Veins Localized at the Basal Unconformity of the Flinton Metasedimentary Group

E.P. Dillon[1]

THIS PROJECT IS PART OF THE SOUTHEASTERN ONTARIO GEOLOGICAL SURVEY (SOGS) WHICH WAS FUNDED EQUALLY BY THE FEDERAL DEPARTMENT OF REGIONAL ECONOMIC EXPANSION (DREE) AND THE ONTARIO MINISTRY OF NATURAL RESOURCES UNDER THE MINERALS PROGRAM OF THE EASTERN ONTARIO SUBSIDIARY AGREEMENT.

Introduction

During the latter part of the 1983 field season, geologists of the Mineral Deposits Section studied the geological setting of 3 vein-gold occurrences in southeastern Ontario as part of the Southeastern Ontario Geological Survey (SOGS) Program. The areas studied include 2 past producers, the Addington Mine and the Ore Chimney Mine, and 1 occurrence, the Ore Mountain (Figure 1).

Field work consisted of detailed geological and structural mapping in the vicinity of the properties in order to become familiar with their geological setting. This work will be followed by regional studies during the latter months of 1983. Suites of samples, collected across the favourable vein zones, will be subjected to trace and major element analysis and thin section study, funds permitting.

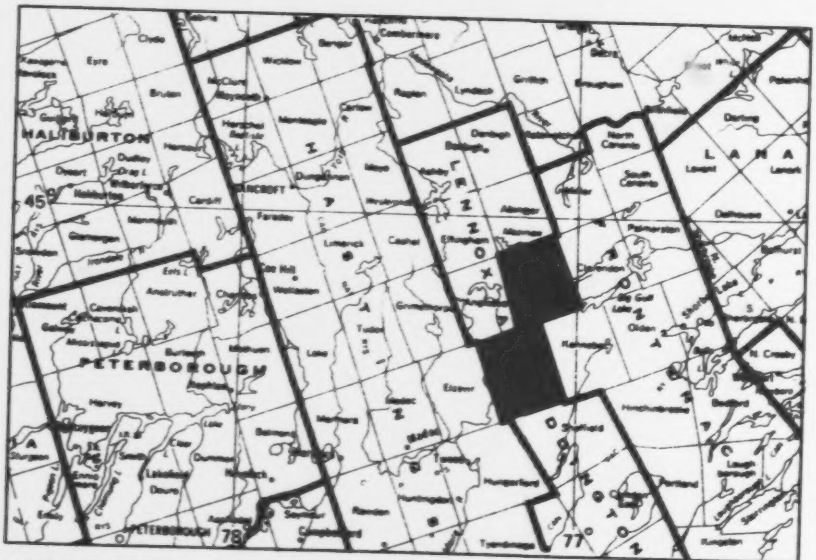
The following discussion is based on literature research and field investigations.

Addington Mine

The Addington Mine is located in lots 24 and 25, concession VI, Kaladar Township. Access to the mine site is via a gravel bush road which runs north from the Flinton Road approximately 1.6 km west of Highway 41.

History of Development

The Addington Mine was discovered in 1881 by the Golden Fleece Mining Company. Initial work on the property began in 1887 by the Adelaide Mining Company of Balti-


HALIBURTON
PETERBOROUGH
L A N A
45
78
77
Eyre
Bruton
Cardiff
Limerick
Cashel
Abinger
Elzevir
Kennebec
Palmerston
Clarendon
Dalhousie
Lanark
Lavant
Darling
Anstruther
Harvey
Methuen
Hungerford
Tyendinaga
Portland
Bedford
Kingston

LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

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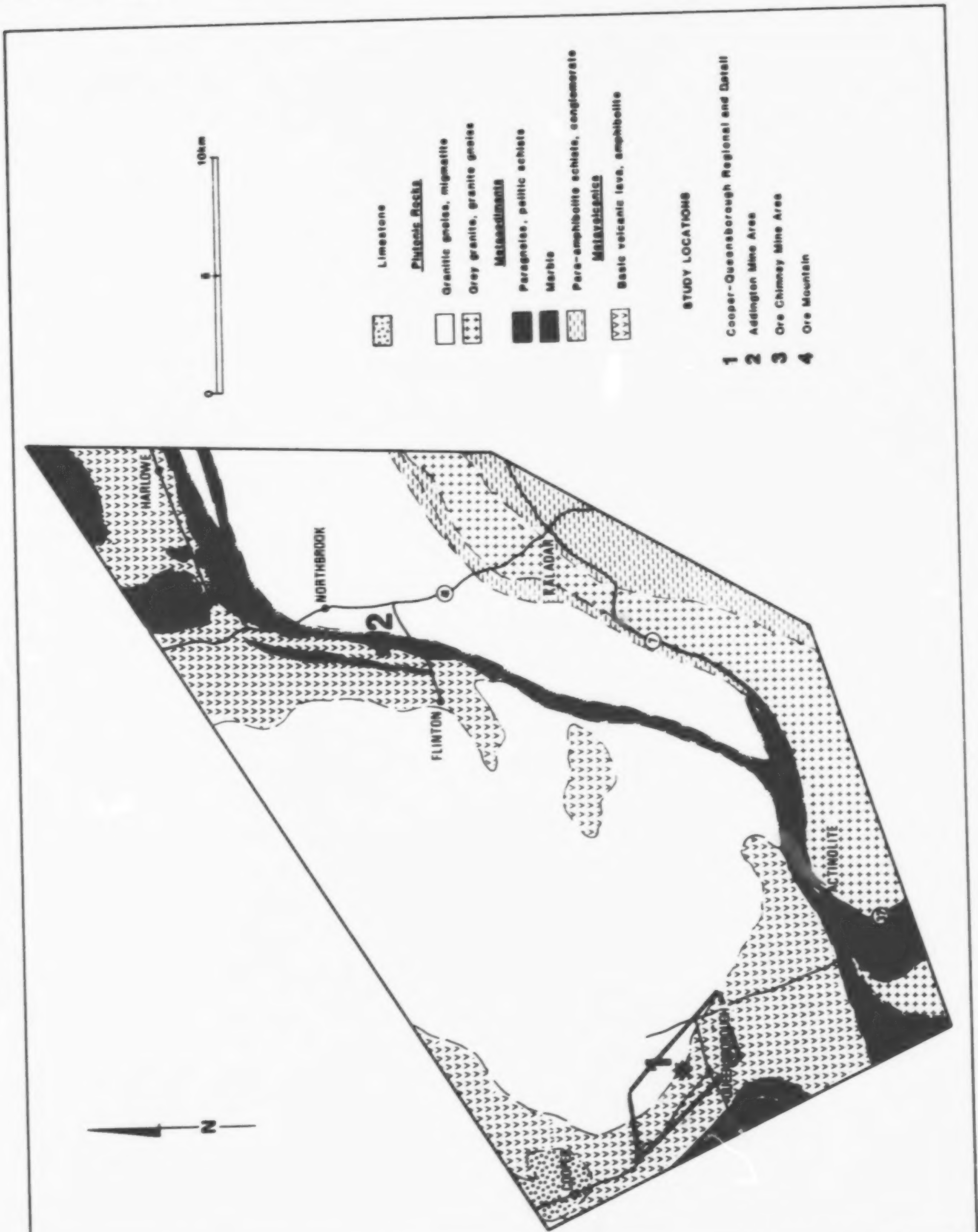
[1] Geologist, Mineral Deposits Section, Ontario Geological Survey, Toronto.


N
HARLOWE
NORTHBROOK
FLINTON
KALADAR
ACTINOLITE
1
2
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10km
Limestone
Plutonic Rocks
Granitic gneiss, migmatite
Grey granite, granite gneiss
Metasediments
Paragneiss, pelitic schists
Marble
Para-amphibolite schists, conglomerate
Metavolcanics
Basic volcanic lava, amphibolite
STUDY LOCATIONS
1 Cooper-Queensborough Regional and Detail
2 Addington Mine Area
3 Ore Chimney Mine Area
4 Ore Mountain

Figure 1 Generalized geology and study locations

more, Maryland, and between 1907 and 1935 various companies conducted surface and underground exploration and plant construction. Production to the end of 1919 consisted of $10 000 from a 10 stamp mill, and in 1922 a cyanide plant was added to the mill (Harding 1944; Wolff 1982). In 1935 the property was acquired by the Consolidated Mining and Smelting Company of Canada Limited (Cominco Limited) which carried out development work including a 535-foot inclined shaft, winze 273 feet below the 500-foot level, levels at 100, 200, 300, 400, 500, 625, and 700 feet, 3033 feet of cross-cutting and 7096 feet of drifting, 8 surface and 68 underground diamond-drill holes. This work proved estimated reserves of 256 000 tons grading $5.60 per ton (0.17 ounce gold per ton at $33.00) with 103 000 tons of probable ore (Source Mineral Deposits Files, Ontario Geological Survey, Toronto). The mill was removed from the site in 1940 and the shaft and larger pits were infilled under Cominco's supervision in 1975. More recently the property has undergone preliminary re-evaluation work by E. & B. Explorations Limited from 1980 to the present.

Geology

The mineralized zone at the Addington Mine is exposed at surface for a distance of 915 m. It consists of a 2 to 10 m wide shear zone, localized at or near the unconformity between the older Tudor mafic metavolcanics to the west and the younger Flinton Group quartzite, meta-arkose and conglomerate to the east (Figure 1). Within this shear zone lenses and stringers of quartz and tourmaline contain arsenopyrite, calcite, pyrite, and gold. Harding (1944) notes accessory ankerite, chalcopyrite, pyrrhotite, and scheelite within the mineralized zone.

The mafic metavolcanics exposed in the Addington area consist of fine- to medium-grained, medium to dark green-black amphibolites. Two textural varieties of amphibolites occur in the Addington area. The predominant amphibolite type consists of a medium-grained, dark green and buff, well foliated amphibolite gneiss. This rock exhibits moderate segregation of felsic and mafic components and often shows acicular amphiboles (0.5 to 1 cm long) along foliation planes. Minor disseminated pyrite and magnetite are the most common accessories, and carbonate, as fine fracture fillings and smears along foliation planes, is present in varying amounts.

Secondary to the gneissic amphibolite is a fine-grained dark green to black variety which is well foliated, often fissile or slaty, and usually carries fine disseminated pyrite. This textural type occurs as fine 0.25 to 0.5 m zones within the gneissic variety and may represent minor shearing along foliation within the thick (1.5 km) mafic volcanic sequence.

A narrow zone of garnet-biotite-amphibolite gneiss occurs at the contact between the mafic metavolcanics and the clastic metasediments. This unit is 0.5 to 2 m wide and is medium grained, dark grey to black, well foliated, and schistose to gneissic in character. It is composed of biotite and amphibole and contains 1 to 5% garnet porphyroblasts (0.5 to 1.5 cm in diameter). The garnets vary from red to dark red-black in colour and the darker varieties are magnetic. Moore and Morton (1980) assign this unit to the basal part of the Flinton Group in the Bishop Corners Formation. In the Addington area all primary bedding has been destroyed and thus no angular unconformity between this unit and the underlying mafic metavolcanics is apparent in outcrop.

The Flinton Group of clastic sedimentary rocks lie unconformably above the Tudor mafic metavolcanics in the eastern part of the study area. Immediately above the metavolcanics is a series of interbedded micaceous meta-arkosic rocks and quartzite pebble conglomerates.

The arkosic unit consists of a massive, medium-grained buff-tan, foliated and well laminated rock composed of muscovite, quartz, feldspar, and varying amounts of biotite. These rocks are well crossbedded and relatively undeformed except for foliation. Foliation appears to intersect bedding at a 30° angle.

The conglomerate units are massive, well foliated rocks composed of 60 to 80% clasts of quartzite (showing earlier crossbedding and fine laminations), milky white quartz, and much lesser mafic metavolcanics in a matrix of buff-tan micaceous meta-arkose. These rocks are interbedded with the meta-arkose units and contacts between the 2 units are usually sharp, showing only occasional grading. Veinlets and pods of white milky secondary quartz occur throughout the clastic sedimentary succession. These quartz pods occasionally contain associated tourmaline; tourmaline also occurs in the matrix of the conglomerate surrounding the quartz-tourmaline pods. Magnetite occasionally occurs within the matrix of the conglomerate and disseminated within some quartzite pebbles. These pebbles take on a bluish grey tint where magnetite occurs.

In the western part of the study area, approximately 1 km west of the mine property, a zone of very calcareous quartzofeldspathic metasandstone occurs (Lessard Formation, Wolff 1982). This unit is light to medium grey, medium grained, and often sandy in texture. Occasional 0.5 m interbeds of coarse-grained gritty sandstone with 5 to 10%, 0.5 to 2 cm quartz pebbles occur within the medium-grained unit. This unit overlies the Bishop Corners Formation in the survey area.

All of the units mapped in the Addington area are well foliated. Minor folding occurs within the volcanic rocks and conglomerates especially near the sheared contact zones between the metavolcanics and clastic metasediments. Faulting occurs within the mapped area, although no horizontal displacement of the various units was observed. The faults are indicated by topographic lineaments on air photos.

Ore Chimney Mine

The Ore Chimney Mine is located in lot 31, concession I, Barry Township, just north of the Harlowe Road, approximately 1.6 km east of Highway 41 (Figure 1).

History of Development

The discovery of gold was made in this area in 1902, and in 1904 the Ore Chimney Mining Company was formed to work the property. They sank a 120 m shaft, drifted for 750 m on several levels, sank a winze from the 120 m level to the 165 m level, and carried out 50 m of drifting on the lowest level. A 20 stamp mill was installed in 1915, however, no concentrates were shipped or treated at this time.

From 1928 to 1932, Bey Mines Limited carried out geological mapping, trenching, magnetometer, and electromagnetic surveys and drilled a total of 1150 m in several holes from surface. In 1932 the shaft and drifts were dewatered and sampled in detail. The present head frame was built by Bey Mines in 1935. In 1944 Eastwebb Mines Limited acquired the property and undertook metallurgical testing of the ore and concentrates. In 1956 Cavalier Mining Corporation Limited carried out additional geological mapping and surface diamond drilling. More recently the property was brought to lease in 1977 by G. Gayle (Moore and Morton 1980).

At the present time the property is owned by Albert Banner of Cloyne, Ontario. During the 1983 season Mr. Banner has dewatered and retimbered the main shaft to the 150-foot level and this drift was opened and accessible for resampling and inspection by mid-August.

Geology

The gold, silver, copper, lead, and zinc mineralization associated with quartz veining at the Ore Chimney Mine is hosted in a 1 to 4 m wide shear zone within the Tudor mafic metavolcanics at the unconformity with the overlying Flinton Group metasediments. The shear zone is very poorly exposed on surface in several old trenches and is traceable for approximately 170 m in an east-west direction.

The mafic metavolcanics (Tudor Formation) exposed on the Ore Chimney Mine property are fine-grained, dark green grey to black, well foliated to fissile amphibolites. This unit is often cut by cross fractures infilled with quartz and quartz-carbonate; carbonate also occurs along foliation planes. Accessory fine disseminated pyrite and magnetite were observed sporadically within the amphibolite sequence.

At the contact with the metaclastics of the Flinton Group (Bishops Corners Formation, Moore and Morton 1980) a 1 to 4 m wide zone of garnet-biotite-magnetite schist was observed. This unit has been placed at the stratigraphic base of the Bishop Corners Formation by Moore and Morton (1980). This unit is medium to fine grained, dark green-black, and well foliated to schistose. It contains 2 to 5%, 1 to 5 mm, dark red, subhedral garnet porphyroblasts and trace to 2% fine disseminated magnetite.

Stratigraphically above the garnet-biotite unit is a 5 to 10 m section of fine-grained, buff-tan to grey, well laminated and massive quartzite. Fine dark laminations and frequent well preserved crossbedding are present throughout the quartzite unit.

In contact with the quartzite unit is a thick section of interbedded quartzite, micaceous quartzite, and quartzite pebble conglomerate. The quartzite units are similar to the lower quartzite with occasional micaceous sections which appear similar to the meta-arkose described above.

The conglomerate observed on the Ore Chimney Property contains 50 to 80% quartz, quartzite, black chert, and minor mafic clasts (2 to 30 cm long) in a buff meta-arkose matrix. These rocks, which are massive and well foliated, outcrop in ridges which parallel their foliation. Occasional zones of a gritty sandstone quartz pebble conglomerate with 10 to 30%, 1 to 3 cm clasts have been observed. However, the exact facies relationships between these rocks and the conglomerate is obscure. Contacts between the quartzite-arkose units and the conglomerates are usually very sharp with no obvious grading between the 2 clastic varieties.

Foliation within the rocks at the Ore Chimney Property trends between 050° and 085° and dips steeply (75° to 90°) to the north. Bedding attitudes within the quartzite-conglomerate sequence are subparallel or parallel to the foliation direction, however, dips are steep to the north or south. Moore and Morton (1980) describe an S-shaped fold within the clastic sequence at the Ore Chimney Property. This folding has been confirmed by the present study. No faulting was observed at the Ore Chimney Property.

Ore Mountain Occurrence

The Ore Mountain Occurrence is located in lot 32, concession I, Barrie Township (Figure 1). Access to the property is via a bush trail which runs south of the Harlowe Road approximately 3 km east of Highway 41.

History of Development

The Ore Mountain Mining Company Limited was incorporated in 1914 and it acquired the mining rights to lot 32, concession I, Barrie Township (Sutherland *et al.* 1915). At this time a small shaft was sunk and several exploration pits were excavated (Meen 1944). No further work has been recorded on the property to the present.

Geology

The Ore Mountain Occurrence is located at the unconformity between the Tudor mafic metavolcanics and the overlying Flinton Group metaclastic sedimentary rocks. Arsenopyrite-gold mineralization is localized in a quartz-stringer shear zone at this contact.

The mafic metavolcanics (Tudor Formation) exposed on this property consist of fine-grained, dark green, well foliated amphibolite. This unit contains minor zones of fine disseminated pyrite and often exhibits fine smears of calcite along foliation planes.

In contact with the mafic metavolcanics to the south is a 3 to 10 m section of fine- to medium-grained, buff-tan, grey to pinkish, well laminated micaceous quartzite. These rocks are well bedded and occasionally crossbedded. Within this sequence are interbeds of a coarse grained gritty sandstone unit which contains up to 20%, 1 to 3 cm quartz pebbles. The gritty unit is medium to dark grey and contains up to 10% biotite.

Stratigraphically above the quartzite sequence is a zone of quartz and quartzite-pebble conglomerate. This unit is typical of the conglomerates within the Flinton Group and consists of between 40 and 80% quartzite and quartz pebbles, varying in size from 2 to 25 cm, stretched parallel to the regional foliation direction. The matrix is buff, and consists of varying amounts of quartz, plagioclase, muscovite, and minor biotite.

Structurally, the rocks at the Ore Mountain Property exhibit a consistent regional foliation which trends 070° to 080° east, and dips steeply to the north. Bedding attitudes taken within the quartzite unit indicate only minor deviations from the foliation, with strikes 055° to 080° and dips steeply to the north. Faulting was not observed within the survey area and only minor folding is evident within the conglomerate unit.

Of the 3 properties discussed, the Ore Mountain Occurrence exhibits the least mineralization. In the vicinity of the main pit, the quartz stringer zone hosted in a sheared biotite-amphibole schist exhibits disseminated arsenopyrite, pyrite, and minor magnetite. The sulphide mineralization occurs as discrete disseminated grains within the mafic schist unit, and comprises up to 10% of the rock. No coarse concentrations of sulphide minerals were found within the quartz vein material.

Discussion

The presence of a regional unconformity between the mafic metavolcanics of the Tudor Formation and the overlying quartzite and conglomerate of the Flinton Group has been well documented (Moore and Morton 1980). The importance of this unconformity in localizing the shear zones which host the mineralization at the Addington, Ore Chimney, and Ore Mountain Properties, however, has not been clearly defined and warrants brief discussion.

The mineralization (gold, silver, pyrite, arsenopyrite ±sphalerite, galena, and chalcopyrite) at the 3 properties described is hosted in quartz-tourmaline stringer zones. These lie within a biotite-hornblende±garnet schist unit conformable to the lower mafic metavolcanic sequence which lies just below the aforementioned unconformity. Bell (1949) noted a gradation at the contact between both the lower metavolcanics and the upper Flinton Group metaclastic rocks. Both become increasingly biotite-rich as the vein zone is approached. The biotite-hornblende±garnet schist strikes parallel to the regional foliation within both the lower volcanic rocks and the sedimentary rocks above, as do the mineralized quartz stringer zones hosted within it.

Based on preliminary field observations and literature research the biotite-hornblende±garnet schist appears to have formed at the unconformity during regional metamorphism. Varying competance above and below it permitted a structural break along which movement and shearing took place. The writer believes the shear zones provided the "plumbing system" into which metamorphically derived hydrothermal mineralizing fluids circulated during the metamorphic event.

Further regional studies on this contact should concentrate on defining the extent of shearing and the development of the biotite-hornblende±garnet schist unit and will provide more detailed regional structural data which will be compared to the areas of known mineralization described above.

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No. S61 Geology of Selected Gold Occurrences in Eastern Ontario

P.S. Barron[1]

THIS PROJECT IS PART OF THE SOUTHEASTERN ONTARIO GEOLOGICAL SURVEY (SOGS) WHICH WAS FUNDED EQUALLY BY THE FEDERAL DEPARTMENT OF REGIONAL ECONOMIC EXPANSION (DREE) AND THE ONTARIO MINISTRY OF NATURAL RESOURCES UNDER THE MINERALS PROGRAM OF THE EASTERN ONTARIO SUBSIDIARY AGREEMENT.

Introduction

Part of the Mineral Deposits Section's 1983 contribution to the Southeastern Ontario Geological Survey (SOGS) program consisted of the structural and lithological mapping of 5 separate areas of known gold and base-metal mineralization. The areas mapped (Figure 1, NTS Sheets 31 C/14,15) include:

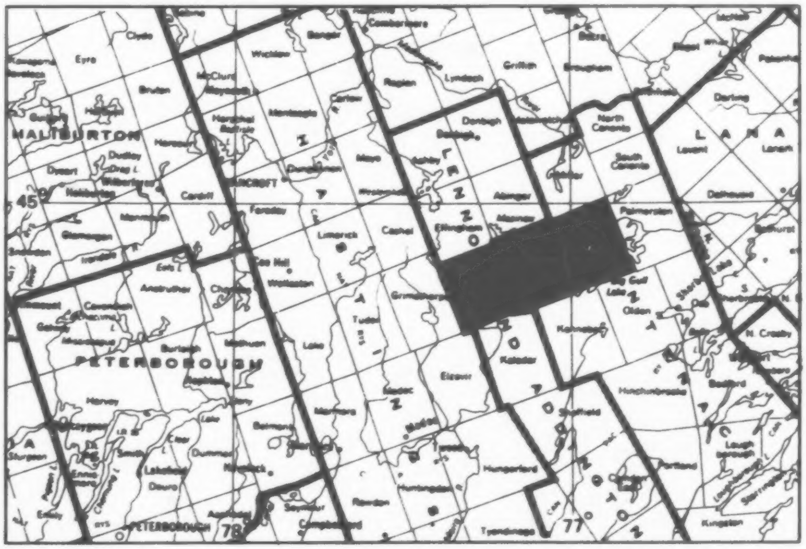
1. the O'Donnell and Ultimate Energy Properties, lot 6, concession III and IV, Anglesea Township
2. the Cook Property, lot 25, concession IV, Barrie Township
3. the Star Gold Mine, lot 24, concession IX, Barrie Township
4. the Hardie Property, lot 3, concession X, Barrie Township
5. the Webber, Boerth, and James Properties which lie between lot 28, concession IX and lot 33, concession IV, Clarendon Township

These areas were mapped at various scales from 1:1000 to 1:5000 and particular emphasis was placed on the structural and stratigraphic relationships between deposits of similar types. The following brief discussions are based on field observations.

Property Descriptions

The O'Donnell and Ultimate Energy Properties

The O'Donnell and Ultimate Energy Properties are located approximately 0.5 km apart (Figure 1). They con-


Clyde
Eyre
Bruton
HALIBURTON
Dudley
Dysart
Cardiff
Glamorgan
Wicklow
Bangor
McClure
Monteagle
Carlow
Faraday
Limerick
Cashel
Wollaston
Anstruther
Chandos
Burleigh
Methuen
PETERBOROUGH
Harvey
Lake
Tudor
Marmora
Madoc
Belmont
Dummer
Smith
Douro
Asphodel
Seymour
Rawdon
Huntingdon
Raglan
Lyndoch
Griffith
Brougham
Denbigh
Ashby
Abinger
Mayo
Grimsthorpe
Elzevir
Kaladar
Sheffield
Hungerford
Tyendinaga
North Canonto
South Canonto
Palmerston
Olden
Kennebec
Hinchinbrooke
Bedford
Portland
Kingston
Darling
Lavant
Lanark
Dalhousie
Bathurst
N. Crosby
L A N A
45
78
77

LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

tain mineralized quartz veins within shear zones and were mapped at a scale of 1:2500 to investigate the possibility of a linear structure linking the 2 properties.

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The geology of Anglesea Township is dominated by a north-trending belt of massive very fine grained to fine-grained, medium- to dark-green mafic metavolcanics. Numerous textural variations include fine- to coarse-grained amphibolites, amphibolite gneisses, and chlorite schists. Pillow sequences, pillow-top breccias, and agglomerate beds represent primary volcanic structures. Minor intermediate (andesite-dacite) flows <5 m thick occur within the thick homogeneous mafic flow sequence.

The shear zones contain mineralized quartz veins within sequences which may represent interflow metasediments or altered silicified and carbonatized mafic metavolcanics. At the Ultimate Energy showing, the host rocks are very fine grained to fine grained buff-weathering, and light to medium grey in colour. Mineralized quartz veins at the O'Donnell Property occur within a dark grey, thinly bedded (<1 cm) very fine grained unit.

The Elzevir batholith, which underlies 300 km^2 in Elzevir, Anglesea, Grimsthorpe, and Kaladar Townships, intrudes the mafic metavolcanics to the west. It varies from diorite and quartz diorite to granodiorite in Anglesea Township (Moore and Morton 1980a, 1980b). To the northeast, the mafic metavolcanics are overlain by a series of calc-alkaline flows with intercalated volcaniclastic and carbonate metasediments (Moore and Morton 1980a, 1980b).

The mafic metavolcanics trend north to northwest and dip steeply west. A series of swamps parallel a similarly trending shear zone whose northern extension is marked by the Ultimate Energy showings (Figure 1). Associated alteration consists of extensive carbonatization, sericitization, and silicification. The shear zone is 50 m wide and 400 m long and contains south- to southeast-trending quartz veins which extend for 150 m and range in thickness from a few centimetres to 2.5 m. Coarsely crystalline calcite, ankerite, biotite, and chlorite are associated with the sheared rocks adjacent to the veins. Metavolcanics within the shear zone are altered to hornblende-chlorite schists. Mineralization consists of pyrite, chalcopyrite, and arsenopyrite and assessment reports state that gold is associated only with the first two sulphides. Assay values from 10 short diamond-drill holes (totalling 435 m) along a strike length of 400 m reveal only traces of gold and silver (Assessment Files Research Office, Ontario Geological Survey, Toronto (AFRO)).

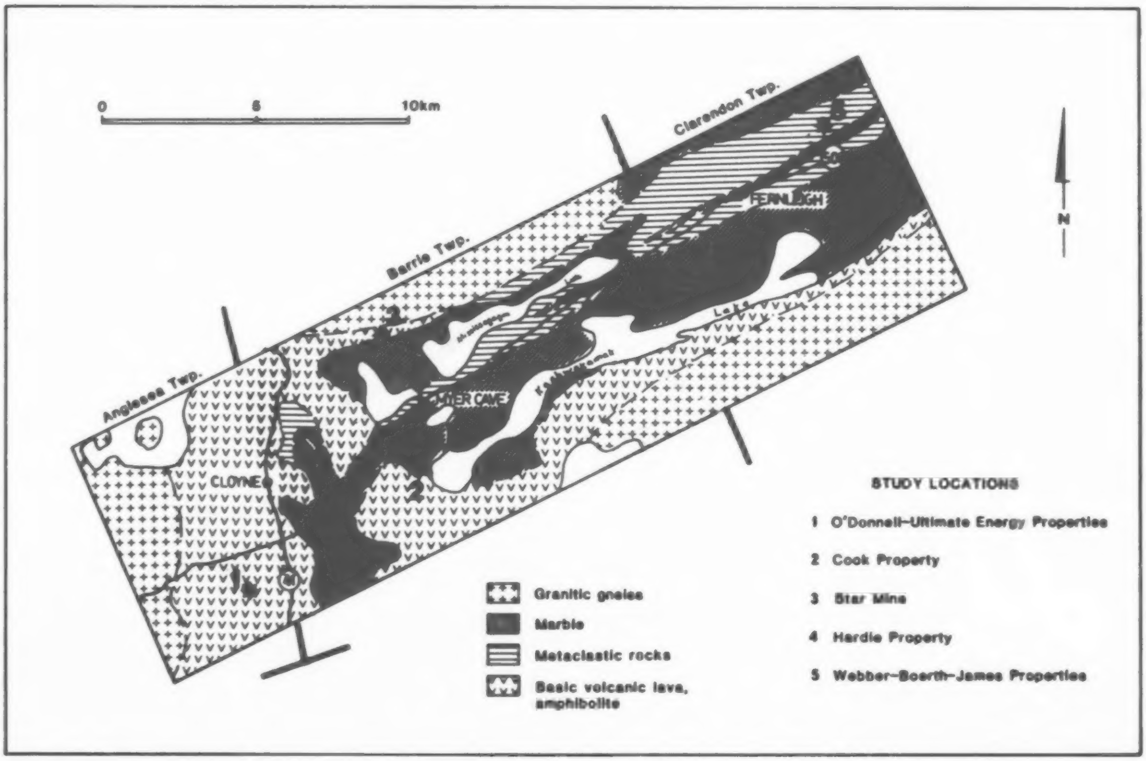
0
5
10km
Clarendon Twp.
Barrie Twp.
Anglesea Twp.
FERNLEIGH
MYER CAVE
CLOYNE
Lake
Kashwakamak
N
1
2
3
4
5
Granitic gneiss
Marble
Metaclastic rocks
Basic volcanic lava, amphibolite
STUDY LOCATIONS
1 O'Donnell-Ultimate Energy Properties
2 Cook Property
3 Star Mine
4 Hardie Property
5 Webber-Boerth-James Properties

Figure 1. Location of study areas.

The O'Donnell showing consists of a series of pits across a 200 m long shear zone. Quartz-ankerite veins and stringers trend N05°E and dip vertically and contain dominantly arsenopyrite mineralization with lesser pyrite, chalcopyrite, galena, sphalerite, and reportedly meneghinite (Meen 1942). Disseminated mineralization and some sections of massive arsenopyrite occur within a shear zone ranging from 0.5 to 3 m wide.

Mineralization shows considerable variation along the shear zone. It is offset by an east- to northeast-trending fault. South of the fault, mineralization is very limited and terminates within 50 m of the fault. An assay of the O'Donnell Property from the Mines Branch, Ottawa (Hurst 1927) showed:

Au	0.14 ounce per ton
Ag	0.56 ounce per ton
As	8.40%
Zn	4.60%
Pb	not determined

Mapping revealed that interflow metasediments within the O'Donnell and Ultimate Energy Properties are not related to the same shear zone and that a number of separate shear zones exist within the thick basaltic assemblage. The homogeneity of the metavolcanics prevents delineation of stratigraphy and makes offset sequences very difficult to recognize.

The Cook Property

The Cook Property is located within a belt of dolomitic marbles with subordinate calcitic beds approximately 500 m north of their contact with mafic to intermediate flow and pyroclastic rocks. The dolomites are massive, very fine grained (0.1 mm), and light brown-to-pink and buff-white in colour. A north- to northwest-trending amphibolite dike intrudes the marbles and parallels the easternmost mineralized pits of the Cook Property. The amphibolite consists of coarse-grained dark grey to black hornblende laths (0.5 to 1 cm) and subordinate calcic plagioclase. Intruding the amphibolite dike and marbles are a series of quartz-feldspar porphyry dikes which form a collapse breccia (Moore and Morton 1980a, 1980b) in the vicinity of the main mineralized zone on the property. The dikes are light grey to green, fine to medium grained with disseminated biotite phenocrysts within a dominantly feldspathic groundmass, and contain between 10 and 30% subhedral to anhedral crystals of feldspar (K-spar?) ranging in size from a few millimetres up to a centimetre.

Structurally, the marbles have predominantly been plastically deformed in the vicinity of the mafic and felsic intrusions. Quartz-feldspar porphyry dikes intrude the marbles with highly variable orientations and have uplifted the marbles to form an alternating ridge and valley topography in the vicinity of the Cook Property.

Mineralization consists of pyrite with chalcopyrite and lesser tetrahedrite, bornite, sphalerite, and galena in quartz-calcite stringers within a dolomitic marble breccia, or as disseminations within the breccia itself. The breccia shows white to light grey dolomitic fragments (a few millimetres to 0.3 m in size) with fragments and blocks of highly sericitized quartz-feldspar porphyry. The silicified dolomitic and calcitic matrix contains irregular bands of biotite. Where quartz-feldspar porphyry dikes transect the amphibolite dike, pyrite, pyrrhotite, and chalcopyrite mineralization occurs within brecciated dolomites and as disseminations within a biotite-feldspar porphyry east of the main set of pits. The biotite-feldspar porphyry may represent a hybrid assimilation product of the mafic and felsic dikes.

Mineralization on the Cook Property is sporadic and is spatially related to breccia zones adjacent to quartz-feldspar porphyry dikes.

An earlier assay of the main pit averaged 0.6% Cu, 6% Zn, 5% Pb, 7 ounces Ag per ton, and 0.05 ounce Au per ton over 4 feet (1.2 m) (Moore and Morton 1980a, 1980b).

The Hardie Property

A number of gold and base-metal properties within the Grenville Province lie along or near the unconformity between the Flinton Group of sediments, and the underlying volcanic rocks and marbles (Moore and Morton 1980a, 1980b; *see*Dillon, this volume).

The Hardie Property (Figure 2) represents one of a series of such properties (others include The Barrie Syndicate - lots 6 to 9, concession X, Barrie Township, and Mazinaw Base Metals - lot 12, concession VIII, Barrie Township), which host gold, silver, and base-metal mineralization within the northeast-trending Fernleigh Syncline (Moore and Morton 1980a, 1980b).

The Hardie Property contains gold and silver mineralization within 2 separate lithologic units. The highest gold values originate from a series of quartz-tourmaline-hematite veins within a 50 m thick light grey to brown, fine- to medium-grained meta-arkose to metawacke gneiss. The unit is traceable for approximately 300 m and immediately underlies the lowermost formation of the Flinton Group, the Bishop Corners Formation, a quartz muscovite schist with varying amounts of staurolite, kyanite, garnet, and biotite (Pauk and Mannard 1982). Immediately underlying the meta-arkose-metawacke gneiss is a series of marbles intruded by numerous mafic dikes, dioritic to gabbroic in composition. Located only 25 m north of the main set of mineralized (pyrite, chalcopyrite, and minor tetrahedrite) quartz-tourmaline veins is a quartz-feldspar porphyry dike (Figure 2).

The quartz-tourmaline-hematite veins within the meta-arkose-wacke unit are reported to have assayed up to 5.70 ounces gold per ton and 0.94 ounce silver per ton from the discovery trench (AFRO).

The second set of mineralized trenches occur within the dolomitic marbles of the Myer Cave Formation, immediately overlying the pelitic schists of the Bishop Corners Formation (Moore and Morton 1980a, 1980b). A series of

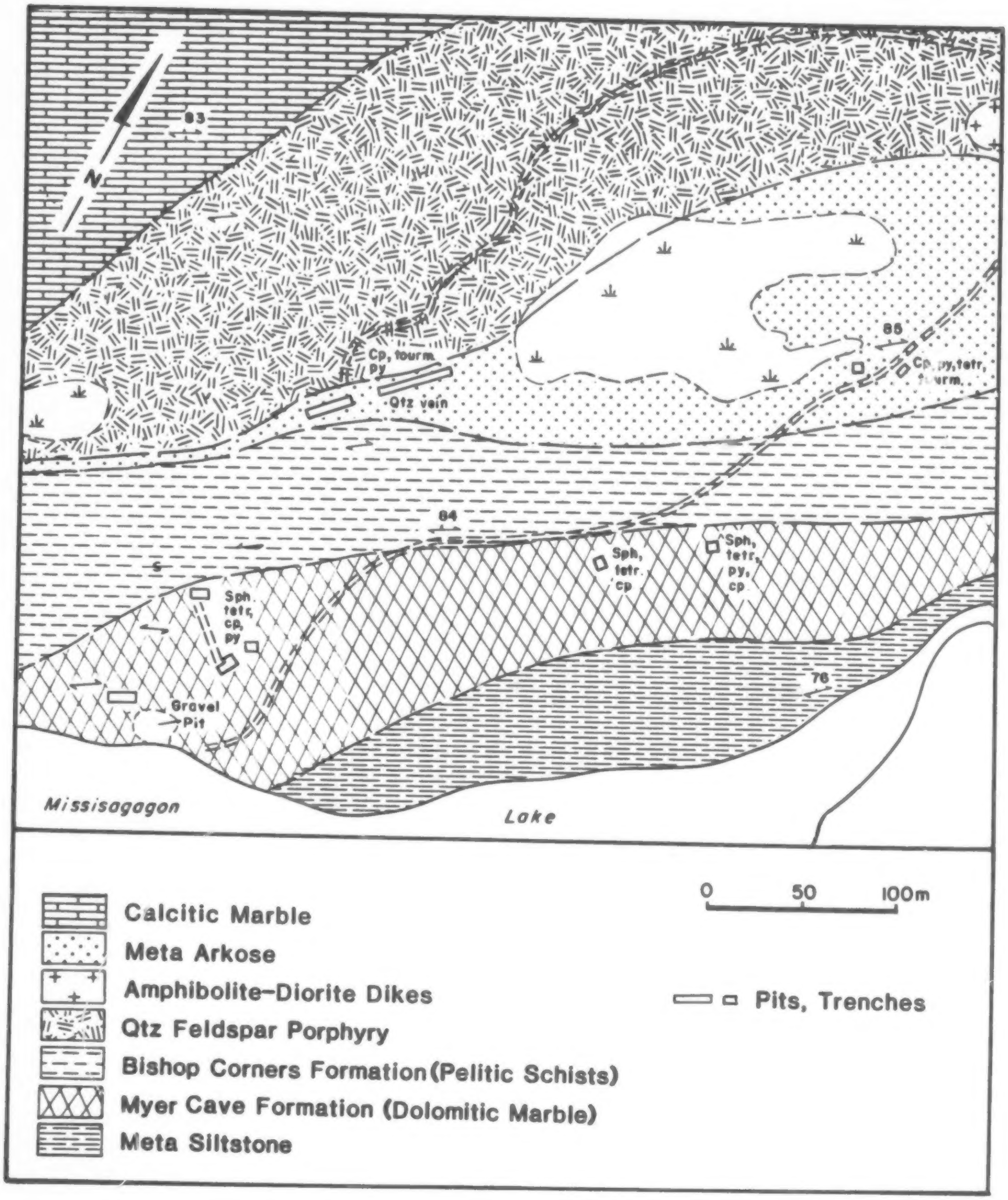
83
N
Cp, tourm.
py
Qtz vein
85
Cp, py, tetr,
tourm.
84
S
Sph,
tetr,
cp,
py
Sph,
tetr.
cp
Sph,
tetr,
py,
cp
Gravel
Pit
76
Missisagagon
Lake
0
50
100m
Calcitic Marble
Meta Arkose
Amphibolite–Diorite Dikes
Qtz Feldspar Porphyry
Bishop Corners Formation (Pelitic Schists)
Myer Cave Formation (Dolomitic Marble)
Meta Siltstone
Pits, Trenches

Figure 2. Hardie Property.

concordant to subconcordant quartz-calcite-tremolite veins carry dominantly tetrahedrite with lesser chalcopyrite, bornite, sphalerite, pyrite, and arsenopyrite. The veins are traceable in trenches for over 300 m within poorly exposed fine-grained tremolitic dolomitic marbles which are strongly folded and steeply dipping. The vein system shows rapid thinning and thickening between the trenches and associated mineralization is sporadic.

Assays indicate that the dolomite marble-hosted quartz-carbonate-tremolite veins are predominantly silver rich. Assay values as high as 46.75 ounces silver per ton have been reported. Minor gold values up to 0.12 ounce gold per ton have been reported from one of these trenches.

The Webber-Boerth-James Properties

The Webber, Boerth, and James Properties represent 3 series of gold-bearing quartz veins in a similar stratigraphic-structural setting. All 3 lie in interbedded marbles and metaclastic rocks along the northern limb of the Fernleigh Syncline (Pauk and Mannard 1982). The marbles are laminated and very fine grained (<1 mm but locally 5 mm) with subordinate very fine grained, silty dolomitic marble interbeds. Overlying and interbedded with the marbles is a metaclastic unit which grades from a fine-grained thinly bedded to laminated metawacke to a fine- to medium-grained thickly bedded biotite meta-arkose. Overlying this unit is the Flinton Supergroup of sediments which, in ascending order includes: the pelitic schists of the Bishop Corners Formation, the dolomitic marbles of the Myer Cave Formation, and the biotite carbonate schists of the Fernleigh Formation which occupy the core of the Fernleigh Syncline (Pauk and Mannard 1982). Mapping at a scale of 1:5000 between the Fernleigh Formation and the properties 1.5 km to the north revealed a series of antiformal and synformal folds within the marbles and metaclastic units.

Near the Webber and Boerth Properties which are 800 m apart, abundant quartz stringers occur within meta-arkose; interbeds and calc-silicate interbeds are seen within the marbles. Two stages of deformation exist in the area; the first represented by the northeast-trending Fernleigh Syncline with major foliation trends parallel to its axial trace and the second deformation represented by folded D_1 surfaces (Moore and Morton 1980a, 1980b). Detailed mapping in the vicinity of both the Webber and Boerth Properties (1:1000) revealed a series of northeast-trending D_2 quartz-carbonate veins located in the vicinity of the properties.

Mineralization at both properties consists of veins bearing arsenopyrite and lesser pyrite in quartz-tourmaline-ankerite veins which trend between N70°E (Boerth Property) and N65°E (Webber Property) and dip vertically.

The Boerth Mine produced briefly during the year 1900 and yielded 13 ounces of gold valued at $208.00. A grab sample collected from the waste pile by Ontario Geological Survey staff (Pauk and Mannard 1982) assayed 18.9 parts per million (approximately 0.55 ounce per ton) Au and 0.44% As.

The James Property located 5 km to the northeast hosts chalcopyrite, pyrite, sphalerite, and galena within heavily silicified and brecciated tremolitic dolomitic marbles. A shaft has been sunk on a 3 m wide quartz vein trending 050° within coarsely tremolitic dolomite. A sample from the James Property collected by field personnel of the Ontario Geological Survey (Pauk and Mannard 1982) yielded 13.0 parts per million (approximately 0.4 ounce per ton) Au, 102 parts per million (approximately 2.4 ounces per ton) Ag, and 0.59% Cu on assay from the Ontario Geoscience Laboratories, Ontario Geological Survey, Toronto.

The Star Mine

The Star Mine produced gold from dolomitic marbles and interlayered dacitic tuffs immediately south of a thick sequence of andesitic pyroclastic rocks. The mine is located south of the Pringle-Mazinaw Lake volcanic centre (Moore and Morton 1980a, 1980b). Pyroclastic metasediments range from lapilli-tuffs to ash tuffs and tuff-breccias. The lapilli-tuffs consist of between 10 and 50% angular to subrounded fragments, generally elongate parallel to foliation. They are of andesitic to dacitic composition. Fragment size varies from a few millimetres to 1.5 m in diameter and averages about 1 cm in the lapilli-tuff and 5 cm in the tuff-breccias. Predominantly dioritic, andesitic, and dacitic fragments occur within a fine-grained chloritic to biotitic groundmass with relict angular to subangular plagioclase crystals. Epidote alteration of the fragments and the plagioclase is common.

Dacitic pyroclastic rocks are interlayered with andesitic tuffs and overlie them as thin bands ranging between a few centimetres and 2 m thick. These thin bands are very common in the vicinity of the mine as interbeds within the dolomitic marbles. Overlying and interbedded with the dacitic and andesitic pyroclastic rocks are dolomitic marbles, very fine to fine grained, and containing tremolitic crystals and sheaths of crystals which compose up to 25% of the rock. Subordinate amounts of crystalline fine- to coarse-grained calcitic marbles occur as layers a few centimetres up to tens of metres thick within the dolomite. Diorite and granodiorite to quartz monzonite intrusive rocks occur north of the pyroclastic metasediments. Immediately east of the Star Mine aplite dikes carry quartz-tourmaline-pyrite veins. Andesitic tuffs and lapilli-tuffs are sheared to biotite schists in the vicinity of the aplite dikes. Skarn type mineralization is encountered where the aplite dikes intrude dolomitic marble. Coarse actinolite crystals (up to 6 cm long), bismuthinite, chalcopyrite, sphalerite, pyrite, and scheelite (reported by Meen 1944) occur disseminated within quartz-tourmaline veins.

Bismuthinite, pyrite, chalcopyrite, and sphalerite also occur as disseminations within adjacent dolomitic marbles. In the main trench area north of the shaft, a concordant quartz-tourmaline vein trending N65°E is associated with massive pyrite in coarse-grained quartz-calcite-actinolite veins. To the east, this vein and the contact between andesitic pyroclastic rocks and dolomite marbles are offset 75 m to the south by a fault. Another fault occurs east of the southwest-trending series of pits associated with the quartz-tourmaline bearing aplite dike. The faults trend north to northwest. The abundance of barren quartz-tourmaline veins located within the northeast-trending diorite and granodiorite to quartz monzonite intrusive rocks as well as those within the pyroclastic rocks suggests that relative permeability may have played a strong role in the localization of sulphide mineralization within the dolomitic marbles. The ubiquitous nature of disseminated pyrite and lesser chalcopyrite within the pyroclastic rocks may represent the source of some of the sulphide mineralization.

Meen (1944) reports that 134 ounces of gold were mined between 1905 and 1907 with an average grade of 0.14 ounce gold per ton. Sampling of the concentrate by Meen collectively averaged 0.35 ounce gold per ton.

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No. S62 Flake Muscovite Potential of Eastern Ontario

Chris P. Verschuren[1]

THIS PROJECT IS PART OF THE SOUTHEASTERN ONTARIO GEOLOGICAL SURVEY (SOGS) WHICH WAS FUNDED EQUALLY BY THE FEDERAL DEPARTMENT OF REGIONAL ECONOMIC EXPANSION (DREE) AND THE ONTARIO MINISTRY OF NATURAL RESOURCES UNDER THE MINERALS PROGRAM OF THE EASTERN ONTARIO SUBSIDIARY AGREEMENT.

Introduction

World demand for flake mica is expected to increase over the next 20 years or more. Scrap and flake mica consumption by manufacturers of electronic and electrical equipment, roofing products, gypsum plasterboard cements, paints, and molded rubber products is forecast to increase modestly in the future. This increase in the rate of consumption could be accelerated by increased usage of flake mica in agricultural applications, thermal plastic, plastic reinforcement, and well drilling, and also as a replacement material for asbestos in certain applications (Zlobik 1980).

Numerous small sheet muscovite deposits, associated with pegmatites, have been exploited in eastern Ontario. However, the economic potential of flake muscovite derived from metamorphosed aluminous sediments has only recently been recognized. This is primarily due to the discovery and the realization of the economic significance of a flake muscovite deposit located some 7 km southwest of the Village of Kaladar. This pelitic schist grades up to 60% muscovite, and was formerly called the Omya Mica Property. It is now called the Kaladar Aimko Property and is presently controlled by Kozumi Limited of Japan.

The Aimko test pit is located on the western half of lot 4, concession V, Kaladar Township, Lennox and Addington County (Figure 1). Kozumi Limited shipped a 200 tonne bulk sample to Japan in the fall of 1981, followed by a 5000 tonne sample in the fall of 1982, for the purpose of testing liberation procedures as well as the marketability of the end product. Since the discovery of the deposit in 1978 by R.C. Young, and particularly in the past 2 years, several companies have been active in exploration programs directed at delineating economic grades of flake mica in the region.

In 1982, in response to industry's interest in flake muscovite, the Mineral Resources Section of Ontario Ministry of Natural Resources in Tweed, headed by P.W. Kingston, began a program to investigate potential areas of high grade flake muscovite. Field mapping of areas which contain pelitic sediments of sufficient metamorphic grade to host high quality muscovite schists were carried out primarily in the Kaladar and Fernleigh-Ardoch areas.

Regional Geology

Mapping in the Kaladar area was confined to a portion of the Clare River Synform, described by Harding (1944), Chappell (1978), and Wolff (1982). The pelitic schists in the Fernleigh-Ardoch area are locally deformed by the Fernleigh Syncline which has been described by Moore and Thompson (1972) and Pauk (1982). Both the Clare River Synform and Fernleigh Syncline fall within the Kaladar-Dalhousie Trough defined by Hewitt (1956), and are 2 of several northeast-trending supracrustal belts separated by metamorphosed plutonic rocks. The Kaladar-Dalhousie Trough was redefined by Wynne-Edwards (1972), who included it in the Hastings Basin, a subdivision of the Central Metasedimentary Belt of the Grenville Province.

The pelitic schists examined in this study are described by Moore and Thompson (1972) and Chappell (1978) as the basal unit of the Flinton Group of metasediments of Late Precambrian age. The Flinton Group unconformably overlies the Mayo and Hermon Groups, which are thick successions of metasediments and metavolcanics, respectively. The Hermon Group metavolcanics are presumed to be the oldest rocks in the region. All of these rocks have been intruded by mafic to felsic plutons.

Kaladar-Clare River Area

Mapping in this area was restricted to the northwestern portion of the Clare River structure defined by Chappell (1978) and included parts of Kaladar, Sheffield, and Hungerford Townships, in Lennox and Addington County (Figure 1). The map area is easily accessible from Highway 7, approximately 3 km west of the Village of Kaladar.

Mapping begun in late 1982 by W.T. Grant and the author has delineated 13 rock units including mafic to felsic gneisses, carbonate metasediments, clastic metasedi-

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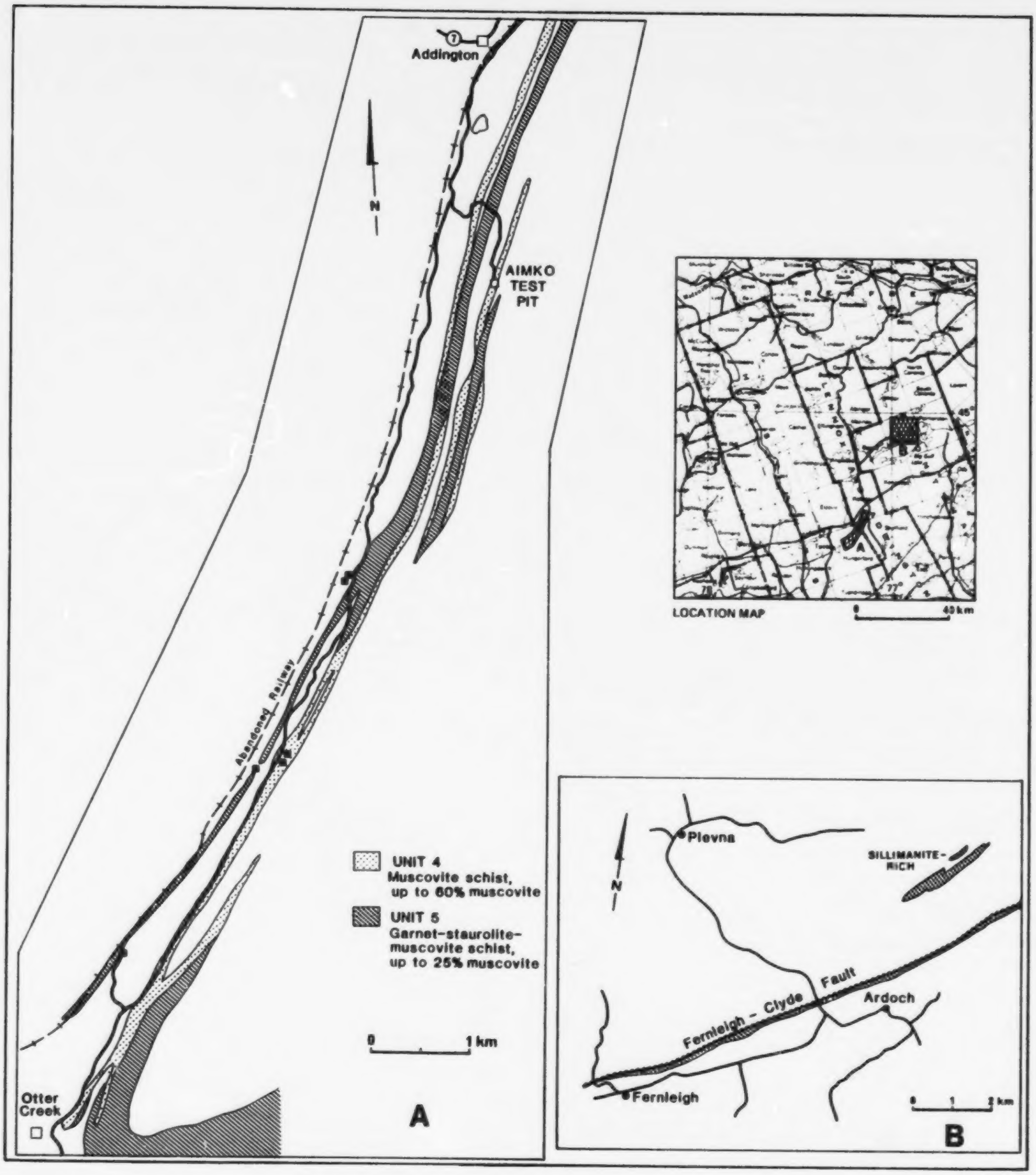
Addington
7
N
AIMKO TEST PIT
Abandoned Railway
UNIT 4
Muscovite schist, up to 60% muscovite
UNIT 5
Garnet-staurolite-muscovite schist, up to 25% muscovite
0 1 km
Otter Creek
A
LOCATION MAP
0 40 km
A
B
Plevna
N
SILLIMANITE-RICH
Fernleigh - Clyde Fault
Ardoch
Fernleigh
0 1 2 km
B

Figure 1. Muscovite deposits: A—Clare River structure; B—Fernleigh-Ardoch area.

ments, and felsic intrusive rocks. The pelitic schists were subdivided into map units, 4 and 5, based on their respective mineral assemblages (Figure 1A). Map unit 4 commonly contains up to 60% flake muscovite, and offers an excellent target for flake muscovite exploration (Figure 1). It is composed of essentially medium-grained quartz, muscovite, and up to 10% magnetite. Accessory minerals include plagioclase and locally up to 10% kyanite. Map unit 4 crops out extensively in the map area, and can be traced for up to 13 km.

Map unit 5 also crops out extensively throughout the map area, and represents a porphyroblastic phase of the pelitic schists. This unit is composed of quartz, biotite, muscovite, garnet, magnetite, and locally staurolite. The muscovite content of this unit rarely exceeds 25%. However, local high concentrations of garnet and staurolite should be investigated for their potential as sources of abrasives.

Several quartzofeldspathic veins paralleling the dominant foliation of the area carry significant concentrations of chalcopyrite and molybdenite. One such vein is exposed in the Kaladar Aimko test pit, in the western half of lot 4, concession V, Kaladar Township.

Fernleigh-Ardoch Area

Pelitic schists in this area are exposed in a narrow but continuous zone on the northern limb of the Fernleigh syncline (Figure 1B) described by Moore and Thomson (1980), and Pauk (1982). The zone begins just south of the Village of Fernleigh in Clarendon Township and extends some 10 to 12 km northeast of Ardoch into Palmerston Township. Another less continuous but wider zone is identified just north of Little Green Lake in Clarendon Township. Detailed mapping of this area has been recently completed by Pauk (1982), which resulted in a comprehensive map, accurately depicting the surface exposure of the pelitic schists of this area. Field examination of these pelitic schists by R.J. Palkovite and the author was conducted in the summer of 1983. Initial observations indicate a low potential for high grade muscovite of any significant tonnage in this belt of pelitic schists. A few high grade (40 to 50%) muscovite zones do occur, however, they are extremely limited in both in strike and width.

Field examination of the pelitic zone north of Little Green Lake shows a potentially economic sillimanite deposit, the main body of which is enclosed by lots 34, 35, concession II, and lots 33, 34, concession III, of Clarendon Township. Sillimanite occurs as ellipsoidal nodules typically measuring 2 to 3 cm along the short axes. This zone commonly contains up to 25% of these nodules and locally grades 60 to 70%.

Initial thin section work in this zone indicates that the nodules are composed of almost pure fibrous sillimanite with very few inclusions. Detailed mapping on the scale 1 cm = 10 m of this property is scheduled to begin in October 1983.

Exploration Guidelines

1. Exploration for flake muscovite deposits should be directed at aluminous metasediments of amphibolite facies, a metamorphic grade sufficient to produce the mineral assemblage muscovite + quartz ± aluminum silicates.
2. Stereoscopic examination of air photos, particularly in poorly documented areas, may help in delineating exploration targets as metapelites of the region almost invariably form poorly vegetated ridges. The outcrop patterns of the metapelites suggest strong structural controls, such as faulting or thrusting, affect their boundaries.
3. Ground magnetic surveys may help find deposits which typically contain from 3 to 10% magnetite, where outcrops are rare, provided that the country rocks are essentially nonmagnetic.
4. Particular care should be taken in accurately assessing the economic potential of any deposit. Muscovite of top quality as a functional filler must have broad, very thin flakes or crystals that can be delaminated to very thin sheets. It must be coarse grained and without inclusions or complex intergrowths. When recoverable quantities of other minerals such as garnet, staurolite, aluminum silicates, and iron-titanium oxides are present, the quality and grade of the muscovite become less important because several commodities may be marketable.

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INDUSTRIAL MINERALS PROGRAM

Introduction by Janet S. Springer[1] and M.A. Vos[1]

Even in economic hard times when base metals cannot be traded, demand for industrial minerals is ensured by the diversity of their use, and the immediacy of their application to everyday life. The importance of this sector of the minerals industry is easily overlooked because in contrast to metals, markets are smaller and more specialized. There is, however, growing recognition that gigantic industrial operations are not the only format for success. Smaller units carefully tailored to local conditions may represent a significant earning power in an economy, carrying with them jobs and other social benefits.

In Ontario, activity in industrial minerals is steadily increasing. The success of such enterprises as Steetley Industries, Steep Rock Iron Mines Limited, Canada Talc Industries Limited, and Manitoulin Dolomite Incorporated has shown that a judicious blending of new technology, market strategy, and acumen can be highly profitable.

The energetic approach of these enterprises is mirrored by a greater investment from the Ontario Ministry of Natural Resources (OMNR) in the whole industrial minerals sector. It is seen in greater staff involvement, in the contract awards made for research in industrial minerals, and by the capital grants to the private sector for modernization.

In the Mineral Deposits Section in Toronto 2 staff members, the authors, are now fully engaged in conducting or supervising industrial minerals projects. In the Industrial Minerals Section of the Mineral Resources Group, work is co-ordinated under the leadership of S.E. Yundt, with D.G. Minnes and J.S. Masham as project co-ordinators. This section also administers capital grants made under the Ontario Government Board of Industrial Leadership and Development (BILD) initiative.

Much additional work is carried out at the Regional Offices of the Ministry. There is also a substantial contribution of projects sponsored by the Ontario Geoscience Research Fund (OGRF).

Program Design

A conventional minerals search program may be based upon efforts to supply users in known markets. For commodities like gold, where demand always outstrips supply, this may be a wise choice. Another approach, which is better applicable to industrial minerals, is to try deliberately to enlarge markets by capitalizing on the diverse functional properties of the materials. One raw material may be processed to the requirements of very different consumers, thereby increasing its sales.

This philosophy has been demonstrably successful for the William R. Barnes Company Limited and for Steep Rock Iron Mines Limited (Northern Miner 1983), the companies who successively owned the Tatlock Quarry. In 1962, this was a producer of low-value marble facing stone, supplying an uncertain market. Today, the resource has been imaginatively transformed into a high-value commodity, from which the present owner retails sophisticated screened filler products in the fine (less than 44, 36, 15, and 2 micron) range (Wood 1983). Steep Rock Iron Mines Limited will soon seek export markets with these fine and ultrafine (<1 micron) products, and has the potential for greatly enlarged sales at home and abroad (Wood 1983; Northern Miner 1983).

Market opportunities are being constantly created by shifts in technology, cost balances, and business practice. Changes in tax structure, improved transport, relative cheapening of energy costs, or new uses developed by materials research for a formerly low-value commodity, can provide a profitable opening for the entrepreneur who is aware and well prepared.

The consequence of this for industrial minerals search is that raw materials must be continuously evaluated. Specifications differ from one use to another; moreover they change with technology. Commonly, because the functional properties are what is valued, substitutions can be made of one commodity for another. The same product may be fabricated from different materials by adapting technology to the materials at hand.

The refractories industry is an example of this adaptation (*see* Springer, "Dolomite", this volume). In 3 major theatres of iron and steel production, Japan, Europe, and North America, 3 quite different technological solutions have arisen to answer the need for cheap, durable furnace linings. These reflect the materials that each area had available.

In Japan, a pyrophyllite-quartz-sericite rock is used as a ladle-lining in secondary metal refining (Hayashi and Nishio 1983). Materials research was concentrated on this raw material to take advantage of its natural characteristics. In Europe, the availability of good refractory dolomite means that a high proportion of dolomite or dolomite-magnesia brick is used (Jeschke *et al.* 1983). The United States makes extensive use of clays and aluminous feedstuffs (Marr 1980; Schroth 1983).

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Raw Materials Supply

For industrial minerals in Ontario, market opportunities may be found if the requirements of the end uses, and current and future plant practice, are carefully examined. Comparison with industrial minerals practice outside North America may suggest new uses for commodities already known to be available.

Advantage may be gained by: supplying a commodity which is vital to existing industrial processes, and whose external supply may be disrupted; substitutes for such vital commodities; or minerals which offer cheaper substitutes in current processes.

If current practice is evolving, there may be a profit in minerals which permit advantageous technological changes towards better or cheaper products; or in minerals which intrinsically save energy, or permit process savings of energy to be made. Minerals that meet stringent health or environmental requirements, or those that substitute for damaging substances in existing processes may also be profitable.

In the category of high-value commodities are minerals whose functional properties make them irreplaceable.

Raw Materials Search

The rationale of cheapness commonly applied to industrial minerals means that material supplies must be sought close to consumer industries and to transportation. This centres the search on southern Ontario. If mineral enterprises are to be successful in highly used land areas, they must be discreetly sought and developed. The ideal will be a pit and plant, small in area, with a life of 20 to 25 years, employing 10 to 25 staff, which produces or partly processes a high-value, non-hazardous commodity. If ideal conditions pertain, this would permit the work force to acquire high technology skills which could be transferred to other industries. At the end of resource extraction, this work force would attract to itself raw materials; it would become preferable to ship materials than to relocate the staff.

Future Prospects in Ontario

Scenarios for Ontario can be built by considering the mineral endowment against market opportunities and production costs. Current work in the province is grouped below to highlight commodity sectors and their raw materials.

Glass, Ceramics, and Refractories

Considerable interest is evident in raw materials for the ceramics-refractories-glass industry. Plastic clays, refractory clays, and high alumina materials, used to raise the firing temperature of ceramic or refractory mixes, would all be sellable, because presently available Canadian fireclays need the addition of alumina to raise their fusion point to the super duty range (1745°C). Aluminosilicates such as kaolin, bauxite, pyrophyllite, and the polymorphs sillimanite, kyanite, and andalusite, are all valued for their refractoriness. In addition, andalusite and pyrophyllite give shape stability to unfired ceramic greenware. Potash feldspar and albitic plagioclases are important constituents of ceramic bodies or glazes.

The industrial superstructure of Sudbury, located close to such large resources as the Indusmin silica quarry at Badgeley Island, suggests that the development of a ceramic industry dealing with refractories, abrasives, and slag ceramics, e.g. abrasion-resistant ceramic tile and fibre glass products, may be possible in the Sudbury area. Large kyanite deposits at Wanapitei and Antoine/Butler Townships are potentially valuable for refractories. The Westree feldspathic sand deposit, north of Sudbury (Guillet 1983a) has potential for the production of fibre glass insulation and coloured container glass.

The interest in the area of ceramics-refractories-glass is reflected in work by both companies and government. Highlights are listed in point form below.

— Sources of rare elements, for sophisticated ceramics use, may result from studies carried out on lithium pegmatites (*see* Breaks, this volume).

— The Industrial Minerals Section (D.G. Minnes) has contracted with the Canada Centre for Mineral and Energy Technology (CANMET) to study a Canadian magnesite for use as a refractory.

— The Mineral Deposits Section (*see* Springer, this volume) is examining materials to substitute for chrome in refractory furnace linings, which are of vital significance in steel making. Partial substitution in refractories may be necessary to safeguard ferro-chrome. Dolomite has been chosen for examination as a substitute.

— In the Grenville Province, Steep Rock Iron Mines Limited drilled a nepheline syenite body in Bigwood Township, and feldspar deposits in Ratter and Hugel Townships.

— Warren Industrial Feldspar Company Limited carried out bulk sampling of a silica deposit in Secord Township.

— The William R. Barnes Company Limited removed 30 000 tons of silica ore from their quarry in the Kingston area for a production test in their Waterdown, Ontario, plant.

— Two Open File Reports on silica in Eastern Ontario, one on high-potential areas (Powell and Klugman 1979), and the other on beneficiation methods (Klugman and Yen 1980) have been published.

— I.P. Martini of Guelph University reported on depositional characteristics and possible industrial uses of silica from the Whirlpool Sandstone (Narain 1983).

— A 2-year study on the detailed sedimentology of early Paleozoic sandstones began in 1983 with OGRF funds granted to Robert Dalrymple and co-workers at Queen's University, Kingston, Ontario.

— The Mineral Sciences Laboratories at CANMET in Ottawa completed a processing study of basal Paleozoic sandstones (Collings and Andrews 1983).

— The Mineral Deposits Section (*see* Springer, this volume) is examining naturally ground and sorted materials of compositions suitable for ceramic and other potential uses, which may represent an energy-efficient alternative in some operations.

— The Industrial Minerals Section has commissioned on contract a revision of "Clays and Shales of Ontario", from G.R. Guillet.

— An inventory of the heavy clay industry and its supplies has been prepared in southwestern region by B.H. Feenstra.

— Thunderbrick Limited assessed the Hicks Lake area for feldspar as raw material for split floor tile.

— Staff at the OMNR Thunder Bay office are mapping the basal Mesozoic unconformity in search of kaolinite.

— A feasibility study on borehole mining of silica sand and kaolinite was completed under a contract with Derry, Michener, Booth, and Wahl, and IMD Laboratories (1983) to assess economic methods of mining deeply buried silica sand-kaolinite clay deposits in the James Bay Lowlands.

Building and Monumental Stone

Dimension stone is currently a flourishing trade in Quebec (Nantel 1983).

In Ontario:

— Building stone is being quarried in McAuslan and Poitras Townships.

— Numerous quarries, most notably the Mill Lake Quarry at Parry Sound, produce flagstone for use primarily as a building stone (Villard 1983).

— Fairmont Granite Limited has been granted $101 000 by BILD through the Small Rural Development Program of OMNR to reopen the Belmont pink granite quarry in Peterborough County, Ontario.

— A market study of the northwestern Ontario stone industry by Les Consultants Sogir Incorporated has been completed and can be viewed in Kenora (Blackburn and Hailstone 1983).

— A literature search and inventory for northwestern Ontario was completed in 1982 (Storey 1983). Polished samples of monumental stone can be seen at the Kenora Regional Geologist's Office (Blackburn and Hailstone 1983).

— W.L. Martin included building stone in an inventory of industrial minerals of the Algonquin Region (Martin 1982a, 1982b, 1982c, 1982d, 1982e, 1982f).

— The Industrial Mineral Section (D.G. Minnes) will commission an illustrated inventory of Ontario building stones.

— A detailed stratigraphy of the Whirlpool (Credit Valley) Sandstone will assist the building stone industry in selecting future resources, and prevent them from becoming "frozen" under alternate developments (Martini and Salas 1983).

— A report on mineral resources of south-central Ontario by G.R. Guillet (1983b), and a study of underground mining (Dynatec Mining Limited 1983) have been completed.

Special Mineral Deposits At or Above the Mesozoic Contact

The tropical interlude which the Mesozoic represents has left characteristic and valuable deposits. Weathering products include kaolinite, lignite, refractory clays, washed silica sand, vermiculite, and lag gravels with concentrations of apatite and columbite.

The known deposits are commonly deeply buried and lie far north, in the James Bay Lowlands, which makes them costly to recover. But by mining several commodities at once a viable enterprise may be possible. The development of kaolinite resources, integrated with the paper manufacturing industry, would stimulate diversification of paper products and raise employment in the area both in quality and quantity of labour. Simultaneous production of fertilizer from phosphates in the Martison and Cargill alkalic bodies could greatly benefit agricultural productivity in the Cochrane clay belt where soils are typically very low in potash.

One of the authors (M.A. Vos) is examining simultaneous integrated development of several commodities from alkali bodies weathered during the Mesozoic. The contract study on borehole mining of silica sand (Derry, Michener, Booth, and Wahl, and IMD Laboratories 1983) is part of a broad approach to the topic.

Interest in deposits of the Mesozoic is shown by the following:

— The Ontario Energy Corporation continued exploration in the Cretaceous basin. In 1982, a helicopter-supported drill program administered by Watts, Griffis, and McOuat Limited sank 18 holes totalling approximately 7600 feet and outlined new lignite discoveries. Sampling of oil shales from the Long Rapids Formation was completed (Luhta and Sangster 1983).

— The Martison Carbonatite alkalic complex 80 km north-northeast of Hearst, has recently been explored by Shell Canada Resources Limited. Geologically inferred reserve estimates of 140 000 000 tons of 20% P_2O_5; 0.35% Nb_2O_5, and as yet undetermined values in rare earth minerals are found at the Mesozoic base (Luhta and Sangster 1983).

— Sherritt-Gordon Mines Limited acquired the Cargill Township phosphate deposit. A bulk sample of vermiculite was tested and met all standards for use as a construction and insulating material. A feasibility study is presently being done on vermiculite production (Luhta and Sangster 1983).

Agricultural Products

Agriculture is a wealth-generating industry. It depends heavily on mineral supplements as nutrition for plants and animals, and on mineral carriers for pest-controlling chemicals. The essential role of agriculture in Ontario's economy means that such mineral products are readily sellable. The basic nutrients in fertilizers are nitrogen, phosphorous, and potassium. Lesser amounts of calcium, magnesium, and sulphur are necessary.

This makes the residual concentrations of apatite (calcium phosphate) developed at the Mesozoic contact above Precambrian alkali bodies an important local resource.

Companies such as Shell Canada Resources Limited and Sherritt-Gordon Mines Limited are exploring alkalic bodies for phosphate and other commodities (Luhta and Sangster 1983).

Current work in this sector follows:

— The Lake Timiskaming Paleozoic outlier is one of the few accessible high-quality lime sources north of Toronto. Plans are presently underway to expand a small existing agri-lime operation to include production of both high-grade lime and agricultural lime (Owsiacki 1983).

— A large carbonate quarry was recently brought into production on the eastern shore of Lake Timiskaming by Exploration Aiguebelle Limited. Annual production capacity is 125 000 tons. Sales forecast for the first 6 months of operation is 35 000 tons of lime for the agricultural industry (Owsiacki 1983).

— Du-Nor Products is exploring local bogs for marl for agricultural liming, and a bulk test will be made. The company plans to expand their staff with increased production (Blackburn and Hailstone 1983).

— Peat production by Diamond Peat Moss Limited in Stormont Township continued in 1982 (Blackburn and Hailstone 1983). This is used as a soil conditioner.

Filler Materials, Carbonate, Talc, and Vermiculite

There are growing markets for fillers of all kinds to serve the paper, plastics, and petroleum products industries. A report and market study on fillers and extenders for Ontario industry is being prepared by G.R. Guillet, under contract to the Industrial Minerals Section.

The variety of interest in this field can be gauged from the items below:

— Steep Rock Iron Mines Limited will receive up to $1.35 million under the BILD program to permit plant expansion. This $5.4 million project will enlarge the Perth plant's fine and medium grind product capacity (Kingston and Papertzian 1983) to meet markets for filler products in plastics and paper, both in Ontario and abroad.

Canada Talc Industries Limited will receive $675 000 for plant and mine expansion under the BILD program. The company mines 25 000 tons per annum (tpa) near Madoc, Ontario. Three high-purity talc products of good colour and brightness are dry-milled to a −44 micron particle size. A talcose dolomite of equally good appearance is milled for filler. These materials, suitable for pharmaceuticals, cosmetics, and lens-polishing, also supply the pulp industry. As extenders and fillers they are bought by paint, plastics, and rubber manufacturers. Granular products include terrazo chips and sand-sized materials for architectural work. The company plans to produce 4 new grades as a prototype to an actual production facility.

Since 1978, Steetley Industries has vitalized the talc operation near Timmins. Its production, once 25 000 tpa, will soon reach 37 000 tpa. The talc products are carefully sized for special high-quality market uses. Principal sales are to the paper industry where Steetley has newly captured a substantial market for a pitch control agent in pulp. Particle diameter averages 2.2 microns in this use.

Another important 2.2 micron product is extender for household and architectural paints. Little talc was used in this way until Steetley developed this use. Products sized at 5.5 and 4 microns sell as fillers in plastics and ceramics. Heat-resistant polypropylene seems a promising area for market expansion. Lesser amounts of talc are used as paper filler and as dusting material in rubber. Recently, Steetley has entered the cosmetics market with a very fine, soft, high-grade material.

— Steep Rock Iron Mines Limited and Canada Talc Industries Limited commenced detailed field evaluation of their properties on parts of the Queensborough Road talc occurrence in 1982. Activity to date has included mapping, sampling, diamond drilling, and limited bench-scale testing of talc zones on both properties. In December 1982, Canada Talc Industries Limited blasted 20 tons from their Queensborough Road Property for a mill test. The company has also been evaluating 2 properties in Cashel Township this year.

— Roger Young of Havelock has been carrying out a detailed exploration program on 2 talc zones in northeastern Madoc Township. Diamond drilling has revealed an impressive talc zone, apparently with good development potential (Kingston and Papertzian 1983).

— Kaladar Aimko Incorporated shipped 5000 tonnes of muscovite ore to Japan in late 1982 for beneficiation testing from a test pit, located southwest of Kaladar on what was formerly called the Omya-Koizumi Mica Prospect (Kingston and Papertzian 1983). The material will be tested as a plastics filler.

— Ram Petroleums Limited processed a small tonnage of tremolite from its Palmerston Township open pit mine during part of the summer of 1982, as an additive for asphalt road construction (Kingston and Papertzian 1983).

— A mineral inventory of Central Region (Guillet 1983b) identified market opportunities for trap rock as roofing granules.

— Field reconnaissance of talc deposits is reported (*see* Dillon, this volume).

— Extender Minerals drilled 1 hole on the former Peerless Canadian Explorations Barite Property in Langmuir Township (Luhta and Sangster 1983).

— The Canadian National Railway obtains a dense, tough, mafic volcanic rock, which retains angularity with abrasion, for the mainline between Thunder Bay and Winnipeg, from the Watcomb Quarry (Blackburn and Hailstone 1983).

— Grenville Aggregate Specialities Limited and Stoklosar Marble Quarries (1969) Limited continued production of marble specialty products and terrazzo chips.

— F.J. Wicks examined the mineralogy and geochemistry of the chrysotile asbestos deposits of Ontario.

— Recent drilling and sampling of Ordovician limestone near Haileybury by Dymond Clay Products Limited revealed shallow, but extensive high-CaO beds (48 to 53% CaO) suitable for good quality lime for smelter operations in Ontario and Quebec (Owsiacki 1983).

— "Chemistry of Grenville Carbonate Rocks" was released in May 1982 (Papertzian and Kingston 1982a). Raw chemical data on analyses of 20 elements from approximately 1700 samples collected in the Eastern Region are reported. Trace element data for 600 of the samples appeared as an appendix to Open File Report 5378 (Papertzian and Kingston 1982b).

— W. Grant and P. Barber completed the Eastern Region marble survey, designed to identify areas of high calcium marble for fillers (Kingston and Papertzian 1983). Seventy sites, where CaO exceeded 54% and $SiO_2 + Al_2O_3$ was less than 1%, were selected for study. This composition, chemically suitable for the filler, lime, and whiting industry, should be low in abrasiveness if required for use as fillers. The 70 sites were assessed at a scale of 1:3600 for tonnage potential, geological continuity, and chemical consistency over a wider area. A final report on this project is anticipated in 1984.

— Staff of the Mineral Deposits Section (J.S. Springer) are testing raw materials for asbestos fibre substitutes. Research at other establishments has shown that glass fibres, comparable in use to asbestos, can be spun from common raw materials at low firing temperatures.

Conclusion

The industrial minerals scene is active and encouraging. The large body of work in progress, both by companies and by government, is a mark of the interest in future developments. Several sectors, such as ceramics-refractories, fillers, and dimension stone show good potential for profit.

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No. 63 Naturally Sorted Materials of Sand Size from Southwestern Ontario

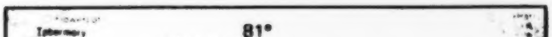
Janet S. Springer[1]

Introduction

Energy is required to grind, sort, and melt materials. For commercial industrial minerals operations, where low cost is of great importance, saving energy can have a marked effect on the profit margin.

There are general relationships between grain size and energy. More work is expended to produce finer grain sizes and therefore the energy requirement increases exponentially as grain size falls. Likewise, sorting to select fine materials becomes more expensive as finer grain sizes are required, and the cost again rises where narrow grain size ranges are in demand. If, because the mineral is dusty or otherwise difficult to handle, wet methods of size classification are needed, energy requirements climb even more sharply because the material must then be dried.

At other stages of processing, however, finer grain sizes may lower energy costs because reactivity and many other behavioral properties are related to surface area. Lavender (1983) has discussed faster melting times for fine glass sands. Trials by the British Glass Research showed that using a −250 micrometre sand instead of a −500 micrometre sand, represented a savings of 18.3% in energy for batch melting.



LOCATION MAP **Scale: 1:1 584 000 or 1 inch to 25 miles**

Geological Implications

If fine grained or closely sized materials are valued but expensive to produce, it makes sense to search out and evaluate deposits which are naturally size-classified by geological processes. Amongst these, wave action and wind transport select minerals to fairly narrow grain size ranges.

There are, however, marked differences in the mineralogical, chemical, and granulometric characteristics of sands produced by differing processes of weathering. All 3 of these characteristics influence the functional properties of the sand, and must be evaluated before the full range of possible uses of the material can be determined.

In practice, naturally occurring materials of sand size are quartz-rich. The more they have been reworked, the greater is their silica content. Very siliceous sands may contain as little as 0.05% Fe_2O_3, less than 2% clay minerals, less than 0.05% heavy minerals (chromite, zircon, monazite etc.) and almost no feldspar (Weiss 1979). In more quickly deposited sands, feldspar, clay minerals, or carbonate may comprise 25 to 30% of the total. Heavy minerals commonly constitute 0.1 to 0.5% in both pure and mixed quartzose sands.

Ontario Sands

Sand-sized materials are widespread in Ontario. They are shown on the physiographic map sheets (Chapman and Putnam 1966) and on the Quaternary map series by the Ontario Geological Survey. The use of sand as aggregate is discussed and documented for Southern Ontario by Hewitt and Karrow (1963), and for designated townships by the Aggregate Resource Inventory Series of the Ontario Geological Survey. For the Eastern Region of the Ontario Ministry of Natural Resources, assessments of sand and gravel are shown on map sheets P.2503 to P.2510, and in Open File Reports 5433 and 5434 by Gorrell and Fletcher (1983a, 1983b).

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Special studies include an examination of the Quaternary Westree sand deposit as a glass sand (Guillet 1983); of the basal Paleozoic sandstone for use in the glass and foundry industry (Klugman and Powell 1979; Collings and Andrews 1983); and of the unconsolidated Mesozoic sands (Derry, Michener, Booth, and Wahl, and IMD Laboratories 1983).

An Example From Southwestern Ontario

Dune and beach sands are extensively developed along the eastern shore of Lake Huron. They are deposits of several ages which have been laid down and then reworked by wind and water. In the Wiarton area, in Bruce County (Figure 1), Quaternary and Recent sands of lacustrine, dune, and beach origin have recently been mapped by Sharpe and Jamieson (1982). The thickness of the deposits is shown on a companion sheet (Sharpe 1982). Lacustrine deposition in glacial lakes of Pleistocene age was followed by eolian winnowing which continues to the present day, or by wave sorting on beaches of various ages.

The earliest sands were lacustrine, laid down more than 10 000 years ago in a transient lake which existed before the glacial Lake Algonquin (Figure 1). The shoreline of this earlier lake stands at 244 to 251 m above present sea level. Glacial Lake Algonquin, which remained for several hundred years (Hewitt and Karrow 1963), left a more marked shoreline at 229 to 236 m above sea level (a.s.l.). Beaches, bars, spits, and widespread sand plains were formed at this stage. Strong winds from the west formed storm beaches which locally rise several metres above the wave-cut platform (Sharpe and Jamieson 1982). The Quaternary events which produced these features are discussed by Karrow and co-workers in greater detail (Karrow *et al.* 1975). Subsequently, as the glacier margin retreated north, Lake Algonquin drained eastwards, exposing the sandy lake bed to wind erosion. Later lakes, ancestral to today's Great Lakes, also deposited lacustrine sands. But, as water levels (e.g. Lake Nipissing at 184 to 198 m a.s.l.) were lower than the Algonquin shoreline, broad areas of active sand dunes developed and have remained active for the last 10 000 years (Terasmae *et al.* 1972).

Mineral Compositions Inferred

An estimate of the mineral composition of these sands can be made from records of the gravel fraction in nearby areas (Table 1). Hewitt and Karrow (1963) give information about 3 localities in Grey County, due east of Bruce County (Figure 1, inset). The ratios of limestone, dolomite, and Precambrian rock fragments are expressed on Map 2039 (Hewitt and Karrow 1963). The Juniper Excavating and E.C. King gravels show 50% and 91% carbonate fragments, respectively; a third locality, shown on the same map near Port Elgin in Arran Township, contains 79% carbonate. The results are summarized below in Table 1, together with the lithologies present.

The composition of dune sands on the Lake Ontario shore is quoted by Hewitt and Karrow (1963) from thesis work by Woodward (1949):

	% grains
Orthoclase and microcline	25
Plagioclase	4
Quartz	50
Calcite	18
Minor accessory minerals: Magnetite, garnet, hornblende, tourmaline, biotite, epidote, etc.	3
	100

Present Studies

The present work will examine and compare the grain size distribution, morphology, and mineralogy of fine sands from the Huron shore that have been reworked to differing degrees by different geological processes. The number of samples at this stage has been limited. If preliminary tests show that the work is promising, a wider selection will be made for more rigorous testing.

A total of 9 samples have been collected; 5 are shallow-water glaciolacustrine sands from the Sauble Valley between Shallow Lake and Sauble Beach (Figure 1). They represent Pleistocene deposits from the pre-Lake Algonquin. One sample is from fossil dune sands of Recent age which are exposed east of the old Lake Nipissing shoreline between Sauble Falls and Spry Lake. One sample comes from dunes between the Lake Nipissing shoreline and the modern beach, immediately south of Sauble Beach North where deposits of the old Lake Nipissing shore are being eroded. One sample is from today's active beach. A final sample comes from a 3 m thick sand overlying worked gravel pits, located on Highway 90 at concession road 8 in Essa Township (Figure 1, inset). The area of sand plain is shown on Map 2226 by Chapman and Putnam (1972).

The characteristics of these sands will be recorded and compared against one another to see what differences are apparent in deposits which differ in age and mode of

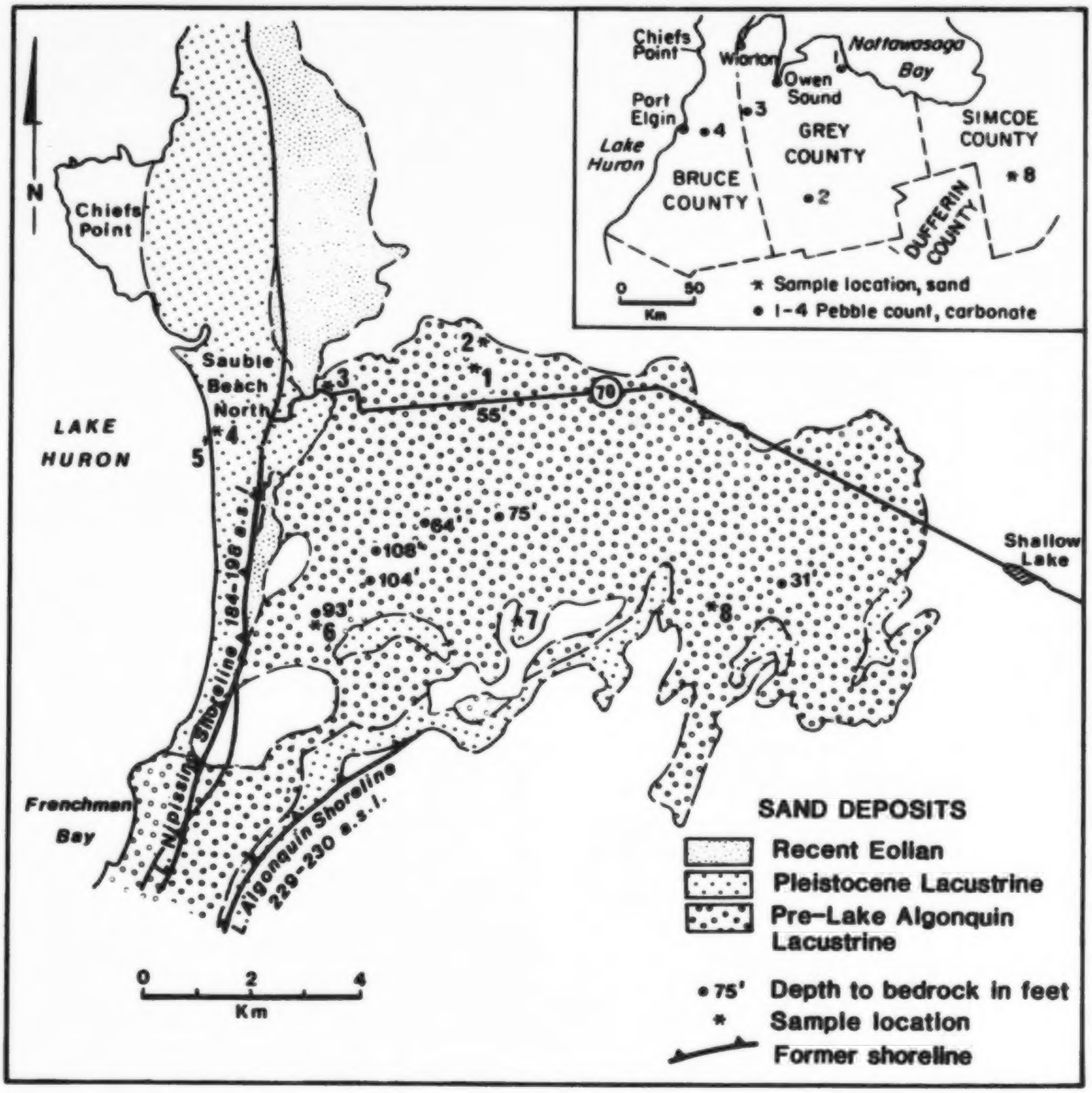
Chiefs Point
Wiarton
Owen Sound
Nottawasaga Bay
Port Elgin
Lake Huron
BRUCE COUNTY
GREY COUNTY
SIMCOE COUNTY
DUFFERIN COUNTY
0 50 Km
* Sample location, sand
• 1-4 Pebble count, carbonate
N
Chiefs Point
Sauble Beach North
LAKE HURON
70
55'
75'
84'
108'
104'
93'
31'
Shallow Lake
Nipissing Shoreline 184-198 a.s.l.
L. Algonquin Shoreline 229-230 a.s.l.
Frenchman Bay
0 2 4 Km
SAND DEPOSITS
Recent Eolian
Pleistocene Lacustrine
Pre-Lake Algonquin Lacustrine
• 75' Depth to bedrock in feet
* Sample location
Former shoreline

Figure 1. Quaternary sands near Sauble Beach (after Sharpe and Jamieson 1982). Inset content after Hewitt and Karrow (1963).

TABLE 1 GRAVEL LITHOLOGIES FROM GREY COUNTY LOCATIONS ON FIGURE 1 (from Hewitt and Karrow 1963)

	FRAGMENT SIZE	FRAGMENT LITHOLOGY	% LIMESTONE/ % DOLOMITE	% PRECAMBRIAN ROCK
Juniper Excavating	1" crush	dolomite limestone calc-siltstone granitic	48/2	2
Durham Stone	1.5" crush	dolomite limestone chert basic igneous metasedimentary	3/90	6
E.C. King	1" crush	dolomite limestone granite metasedimentary	21/70	9
Port Elgin locality	—	—	21/58	14

formation. These characteristics will then be available for comparison against known specifications of sand-sized materials in a wide variety of applications.

Discussion

In Ontario, much emphasis has been placed on materials suitable for coarse aggregate, or for those pure enough to serve the glass or ferrosilicon industries. The present work will examine materials of sand size for the many other, but smaller, markets which exist.

Silica sand is used as concrete aggregate (Minnes 1967) and mortar aggregate; for lime-sand blocks and concrete roofing tile; and to fill moulded shapes bonded with epoxy (Weiss 1979). There are applications as an abrasive, in scouring, buffing, and polishing compounds. It is used as a filter medium or for hydraulic fracturing in oil and gas wells where sand grains, forced into the fracture planes of the rock, increase the effective permeability of the host (Murphy 1960).

In addition, materials research from Europe (Fiori and Fabbri 1983; Bansaghi and Szilagyi 1983; Rak *et al.* 1982; Fekelldshiev *et al.* 1979) suggests that quartz-feldspar mixtures of different origins may be used as ceramics feedstuffs, for stone ware, glazes, sanitary ware, and other ceramic bodies. The feldspathic sands of Ontario therefore warrant further evaluation.

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No. 64 Asbestos Fibre Substitutes from Everyday Raw Materials

Janet S. Springer[1]

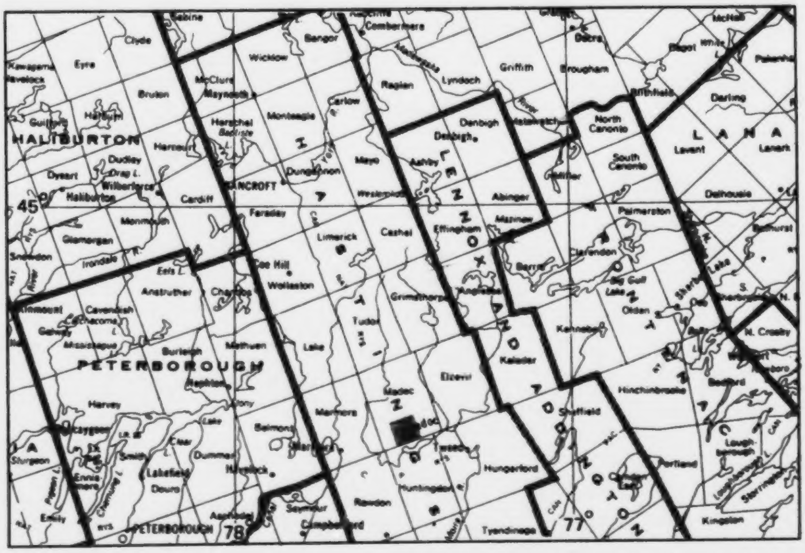
Introduction

It is estimated that 70% of Canadian asbestos fibre is used for construction products (Clarke 1982), where its fibrous nature reinforces and adds mechanical strength to materials such as roofing, plastics, floor tile, and cement products. Crocidolite is the strongest natural mineral fibre of the several asbestiform minerals known.

Worldwide, the greatest volume of asbestos fibre goes into making cement sheet and cement pipe. Long-fibred varieties are particularly valued in the production of large-diameter pressure pipes made of asbestos cement. Expensive long-fibre chrysotile or less costly long-fibred crocidolite is blended with short staple chrysotile to the required reinforcing strength. In general, using crocidolite permits the use of larger quantities of the cheaper, short-fibre chrysotile and keeps down the cost.

Health Concerns

The role of asbestos in precipitating lung disease has been empirically known since the first century A.D. (Canada Centre for Occupational Health and Safety 1981, p.50). In recent years more rigorous studies suggest that crocidolite is more frequently associated with the development of lung cancer and mesothelioma than amosite, and that chrysotile poses less risk than either of these (Health and Safety Commission 1979). Short-staple asbestos (fibres <5 micrometres long) appears to be no more damaging than dusts of other minerals (Pott and Fredericks 1972; Bogovski *et al.* 1974; Wagner *et al.* 1973). This conclusion is also reached by Gross (1974), who quotes evidence from Klosterkötter (1968), and Timbrell and Skidmore (1968). Gross discusses his own evi-


HALIBURTON
PETERBOROUGH
LANARK
BANCROFT
Eyre
Clyde
Bruton
Havelock
Guilford
Harburn
Harcourt
Dudley
Drag L.
Dysart
Wilberforce
Haliburton
45
Cardiff
Monmouth
Glamorgan
Snowdon
Irondale
Eels L.
Anstruther
Chandos
Cavendish
Galway
Mississagua
Burleigh
Methuen
Harvey
Lakefield
Douro
Smith
Dummer
Havelock
Belmont
Marmora
Emily
Sturgeon
PETERBOROUGH
78
Asphodel
Seymour
Campbellford
Sabine
Bangor
Wicklow
McClure
Maynooth
Herschel
Carlow
Monteagle
Dungannon
Mayo
Faraday
Limerick
Cashel
Coe Hill
Wollaston
Tudor
Lake
Grimsthorpe
Madoc
Elzevir
Rawdon
Hungerford
Tyendinaga
Combermere
Raglan
Lyndoch
Griffith
Brougham
Denbigh
Ashby
Abinger
Effingham
Mazinaw
Barrie
Clarendon
Palmerston
North Canonto
South Canonto
Brightside
Darling
Lavant
Lanark
Dalhousie
Bathurst
Kennebec
Kaladar
Olden
Big Gull Lake
Sheffield
Hinchinbrooke
Bedford
Portland
Loughborough
Kingston
N. Crosby
77

LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

dence and, in a rebuttal, quotes several other authors whose results are different.

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Environmental hygiene, of course, influences the results obtained. The manner of processing and the use of these fibrous materials must be carefully evaluated if their effect on health is to be properly assessed. Muir (1980), who was requested by the Canadian Centre for Occupational Health and Safety to comment on 4 major reports for the Royal Commission on Asbestos, discusses this fully.

Although, in fact, risks perceived for different fibre lengths may reflect differences of environmental hygiene, there is now sufficient circumstantial evidence to cause public concern (Health and Safety Commission 1979). European countries have increasingly opted to reduce asbestos usage to a minimum; in the United Kingdom a voluntary ban by industry on crocidolite has been in force since 1969; and West German industry has recently agreed to reduce the asbestos fibre content of cement products over the next 3 to 5 years, using substitutes for reinforcement. The Scandinavian countries and West German representatives to the European parliament have urged a total ban on asbestos be achieved over 5 to 10 years (Clarke 1982).

Substitutes for Asbestos

In many applications as an insulation, a filler or as reinforcement, alternatives have been found for asbestos fibre, which function as well as the original. In cement products, however, no substance yet can cheaply match the tensile strength and chemical resistance at high temperatures of natural asbestos. Zirconia-fibre, which is comparable in properties, is much more costly, averaging $US 1000 a ton, compared with $US 250 to $US 500 per ton for chrysotile.

The need for a cheap, fibrous substitute in cement products is however very great because of pressures from several directions. Asbestos cement technology is relatively simple; the materials are cheap. Clarke (1982) comments:

> . . .the cheapness of asbestos cement pipe compared with the alternatives will maintain its market share particularly in the developing world. A major advantage in this respect is the comparatively simple technology which is required to manufacture asbestos cement pipe, a factor of overriding significance in the developing world where the need for housing, water, sanitation, sewerage facilities far outweighs any potential health hazard.
>
> So far as the medium to longer term outlook is concerned the major producing companies in Canada are placing greater emphasis on marketing to the developing Third World countries where the rates of economic growth are measurably higher than in western world countries and where the clamour for asbestos substitutes has not taken place. Large projects in the Middle East, India, and Mexico for irrigation and cheap housing provided buoyant markets for asbestos cement products during 1981.

The dilemma this implies is sharpened by knowing that if Canada does not supply these countries, the increasing production capacity of Russia, Turkey, and China will do so (Clarke 1982).

New Fibre Substitutes in Cement Products

Recent work by the United States Bureau of Mines (MacKenzie 1981) has shown that ceramic fibres as substitutes for asbestos can be made cheaply from mixtures of slate and limestone. In contrast to normal glass fibre, which suffers chemical attack in cement mixtures, the alkali resistance of the ceramic fibres closely approximates that of chrysotile and exceeds that of zirconia-glass fibre.

Very long fibres suitable for reinforcement of pressure pipes can easily be made from the melt. As lung damage seems to be associated with fibres less than 3 microns in diameter (Pott 1972; Bogovski *et al.* 1974), adverse effects can be avoided by fabricating fibres outside this range.

The raw materials for these ceramic mixtures are cheap and plentiful. Melting temperatures of 1400°C in air compare advantageously with 1650°C needed for zirconia glass. These slate-limestone ceramic fibres appear a promising substitute for asbestos in many cement products.

Fibre Research

Canada Centre for Mineral and Energy Technology (CANMET)

The Mineral Processing Laboratories at CANMET have been engaged in fabricating and testing mineral fibres since 1979. The interest in mineral fibre as insulation is reflected in publications by Winer and Wang (1980), Quon and Wang (1980), Wang and Quon (1980, 1983). Starting materials such as asbestos tailings, blast furnace slag, trap rock, and nepheline syenite waste, with limestone and sand admixtures have been used.

A wide variety of materials can be used for good fibre production. Melt viscosity shows itself to be a direct indication of spinability (Schubert *et al.* 1979). The optimum viscosity is 500 to 1500 centipoise at 1500°C and 1400°C respectively (Zhilin 1950). The choice of starting materials for fabrication then depends on what cheap supplies are available and how low a melting temperature can be used.

Recent work by CANMET (R.K. Collings, S.S.B. Wang, personal communications, 1983) involves the search for alkali-resistant glass fibres to replace costly zirconia-glass fibre. A variety of materials are being tested and results should be available early in 1984.

TABLE 1 **CHEMICAL COMPOSITIONS OF SLATE FROM VERMONT, UNITED STATES, AND MADOC, ONTARIO. Analysis locations shown on Figure 1.**

	VERMONT SLATE	MADOC SLATE			
	COMPOSITIONAL RANGE	VERSCHUREN 1983 (sample MW2)	MILLER AND KNIGHT 1913 (sample MW3)		
SiO_2	55-67	65.0	56.40	52.92	53.90
Al_2O_3	11-19	14.6	17.80	16.69	20.71
Fe_2O_3	1-9	9.82	7.52	9.75	8.31
CaO	0.5-4	0.26	3.67	4.36	3.15
MgO	2-5	1.38	3.45	2.38	0.34
K_2O	3-6	3.77	4.38	5.36	5.83
TiO_2	other oxides not given	1.59			
FeO		0.00	1.53	counted with Fe_2O_3	
MnO		0.02			
Na_2O		0.21	0.75	0.80	0.76
P_2O_5		0.09			
CO_2		0.08	trace	—	—
S		0.01			
H_2O		0.0	4.42	7.32	6.88
		97.33	99.92	99.58	99.88
L.O.I.*		2.60			

*Loss on Ignition

United States Bureau of Mines

A recent project contracted to the Department of Materials Science and Engineering at the University of California in Los Angeles by the United States Bureau of Mines (USBM) on alkali-resistant ceramic fibre, describes results of experimental work on slate-limestone mixtures (Mackenzie 1981). Patent disclosures have been made to the USBM and actions are pending. Further work will evaluate optimum ceramic mixtures; will investigate the surface characteristics that make these fibres resistant to alkalis; and will test other raw materials. At the same time the USBM has contracted with the Manville Service Corporation to demonstrate industrial-scale fabrication of these fibres (Industrial Minerals 1983). Results of both will presumably be available through the USBM.

Mackenzie's experimental work so far suggests that the base glass formulation (50% by weight slate to 50% by weight limestone) is more resistant to alkaline attack that zirconia-glass, both in powder and fibre form. Changes in the iron and calcium content of the melt did not improve this characteristic. One exception is a glass containing 40 mol percent MgO and no calcium or iron. This showed the highest alkali resistance obtained.

Measurements of tensile strength after pressurized heat treatment in calcium silicate paste showed that both zirconia-glass and all the ceramic fibres were less strong after treatment. Mackenzie (1981) concludes that this is not due to chemical attack, but rather to mechanical damage when the fibres were extracted from the hardened cement. Fibres of the base glass composition (averaged from measurements on 50 samples) were slightly stronger than commercial alkali resistant glass, containing 21% ZrO_2. Calcium-glass fibre with no iron and magnesia was weaker.

Application to Ontario Resources

A 50-50 weight percent mixture of limestone and Vermont slate are the starting materials for the "base glass" formulation described by Mackenzie (1981). The range of typical chemical compositions of Vermont slate is shown in weight percent of oxides in Table 1. Beside it are analyses of slates from Madoc Township, Ontario (Miller and Knight 1913; Verschuren, Project Geologist, Ministry of Natural Resources, Tweed, personal communication 1983).

Geological mapping has outlined the extent of the slates and has shown the distribution of both calcite and dolomite limestones in the vicinity (Figure 1). Raw materials for testing are obviously available in quantity close to transport routes.

Geological Background

Low-rank metamorphic rocks of Grenville age are exposed in Madoc Township which lies about 190 km northeast of Toronto. The geology is shown at 1:31 680 on the Ontario Geological Survey Map 2154 which accompanies Geological Report 73 (Hewitt *et al.* 1968). Earlier mapping (Miller and Knight 1913) distinguishes calcitic and magnesian limestones in parts of Madoc and Huntingdon Townships at 1:12 000. NTS map sheets 31 C/5,6,11,12 named Campbellford, Tweed, Kaladar, and Bannockburn, respectively, cover the area at 1:50 000. Recent geological mapping, with particular emphasis on carbonate stratigraphy, has been carried out by the Ontario Geological Survey (Bourque 1981, 1982). The maps and final manuscript are in press. Further regional mapping of the township has been undertaken by the Regional Office of the Ministry of Natural Resources in Tweed . This work will include a map and a new geological evaluation (Verschuren, Project Geologist, Ontario Ministry of Natural Resources, Tweed, personal communication, 1983). Verschuren (1982), and Dillon and Barron (1982) have conducted special searches for talc in the township and Carter (1980) examined the volcanic-hosted pyrite deposits. Limestone resources and much other information are given by Miller (1904). Hewitt (1960, 1964) and Hewitt and Vos (1972) discuss the limestone industries in several publications.

Ontario Materials for Testing

Eight 2 kg samples of slate and limestone, collected from the localities shown on Figure 1, have been submitted to

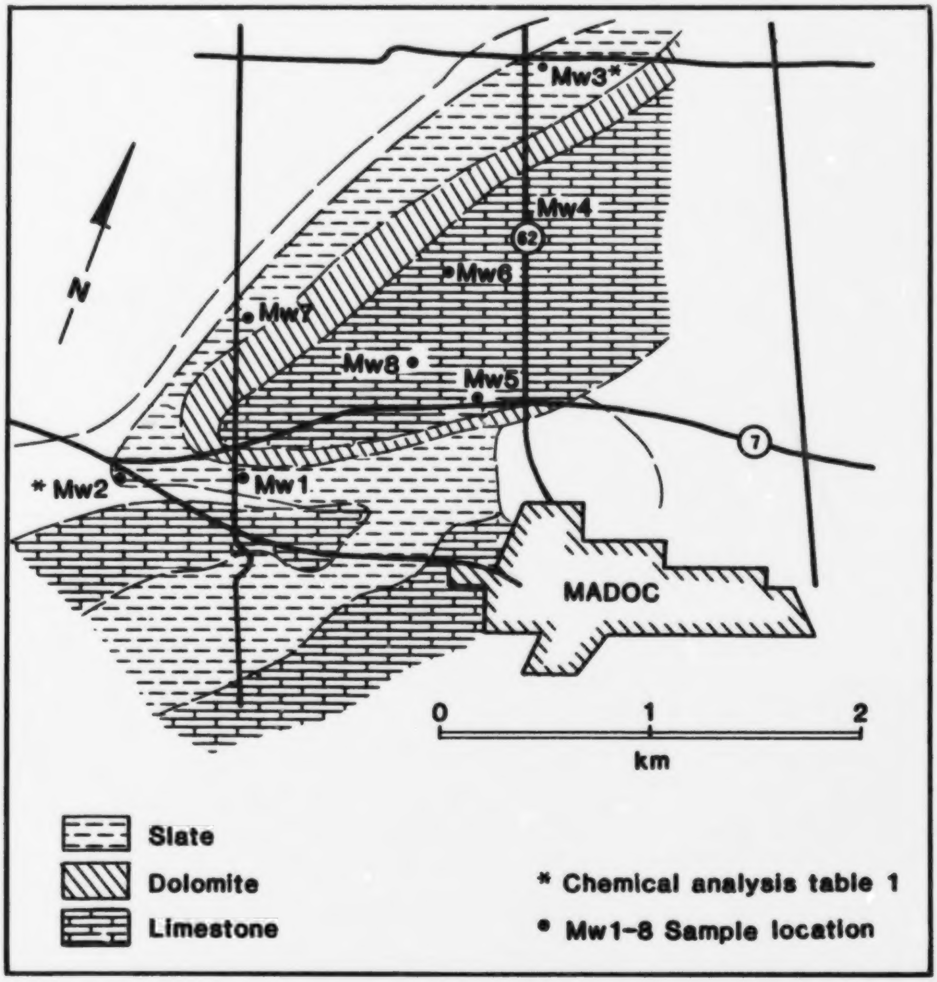

Figure 1. Simplified geology of the Madoc area (after Hewitt 1968; Miller and Knight 1913; Marika S. Bourque, Geologist, Ontario Geological Survey, Toronto, personal communication, 1983).

CANMET for testing of viscosity and alkali-resistance. If both tests are favourable, work on fibre quality may be conducted on bulk samples.

Four slate and four limestone samples have been chosen to represent a spread across the Madoc syncline, and then paired for testing in the following order: 2 and 8; 3 and 4; 1 and 5; 6 and 7. Although other combinations may be made later, the pairs selected lie geographically close, so that a fabricating plant could minimize transportation costs for raw materials.

The effects of calcium on the base glass formulation will be evaluated for its influence on alkali resistance, spinability and melt temperature. If results are favourable, tests may continue in order to evaluate the role of magnesium. It may be possible to establish a compositional range which gives good alkali resistance and spinability at reasonable temperatures.

If experiment shows that magnesian or siliceous magnesian raw materials are required, the geology already indicates that such materials are abundantly available close at hand.

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No. 65 Ontario Precambrian Dolomite as Refractory Raw Material

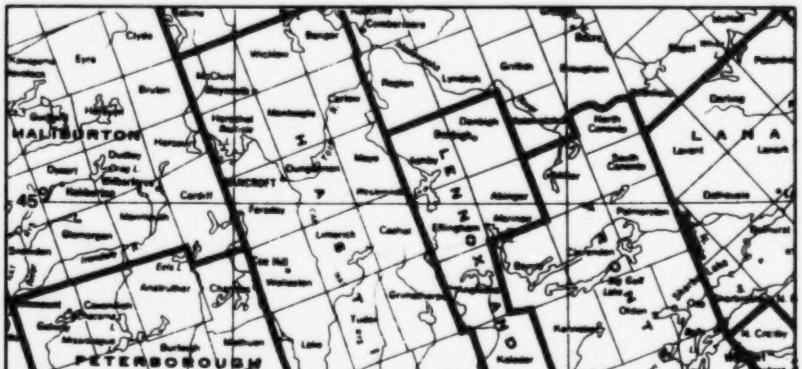
Janet S. Springer[1]

Introduction

Several trends suggest that it would be prudent to examine Ontario dolomite as a domestic supply for refractory furnace linings. At least 3 lines of reasoning contribute to this argument.

Firstly, chromium, a metal essential to modern industry (Energy, Mines and Resources Canada 1982), is vulnerable to interruptions of supply. Ninety-five percent of the world's chromite which is economically extractable with today's technology is concentrated in South Africa, the USSR, and Zimbabwe (Mining Journal 1981). Canada is further dependent on its trading partners as all Canadian chromium is imported via a middleman. Ferro-chromium, the material of most critical importance, is transhipped via Mozambique from South Africa, or via the United States from the Phillipines or South Africa (Energy, Mines and Resources Canada 1982).

Chromium is vital for speciality steels, alloys, and chemicals, and in these uses cannot be substituted (United States National Materials Advisory Board 1978). But in its use as a refractory lining for ferrous and non-ferrous furnaces, for cement kilns, and foundries, it may partly be replaced by magnesia and other compounds. Fifty percent of the chromite used by the United States refractory industry, in 1981, 29 000 short tons of contained chromium, could be replaced by using magnesite-chrome (30 to 40% chromite) instead of chrome-magnesite (70% chromite) materials (Energy, Mines and Resources Canada 1982). The importance of this saving can be gauged by comparison with the 18 000 short tons of chromium needed for plating, a use where chrome is irreplaceable (Papp 1983). Similar reasoning applies to the Canadian steel industry. In the event of a supply crisis, chrome steel



LOCATION MAP **Scale: 1:1 584 000 or 1 inch to 25 miles**

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[1] Geologist, Mineral Deposits Section, Ontario Geological Survey, Toronto.

production could be safeguarded by substituting magnesia for chrome refractories. But this requires that materials research and the search for magnesium-rich raw materials be well advanced (Energy, Mines and Resources Canada 1982, p.46).

Secondly, the evolution of the iron and steel industry has itself favoured a change towards magnesia-rich materials. Peatfield and Spencer (1980) show how, as open hearth furnaces were replaced in the 1970s by basic oxygen and electric arc furnaces, the proportion of magnesia-based refractories rose. Future trends are discussed by Schroth (1983) for the United States, by Hayashi and Nishio (1983) for Japan, and by Jeschke *et al.* (1983) for Germany. These authors show that for these major steelmaking nations the desulphurization of iron and steel, ladle-refining, and the greater use of strand casting, are important means of increasing efficiency and reducing energy costs.

Special refractory linings are needed when secondary metal refining is carried out in ladles. Different technologies to devise cheap, durable linings are arising in the major steel making countries, reflecting both the historical development of the industry and the raw materials available in each country.

In Japan, a pyrophyllite-quartz-sericite rock of particular grain size and texture (Hayashi and Nishio 1983) has been used for refractory linings. In this instance, materials research, concentrated around the available raw material, has capitalized on its particular natural characteristics. In Germany and much of Europe, the availability of very good refractory dolomite at a quarter of the price of magnesia (Jeschke, p.15, discussion in Schroth 1983) means that a high proportion of dolomite or dolomite-magnesia brick is used.

In the U.S., cheap energy to produce energy-intensive magnesia and a steel-making industry which tolerates lesser degrees of basicity and heat resistance in liner materials, has led to the extensive use of clays and aluminous feedstuffs (Marr 1980; Schroth 1983). There has been little tradition of dolomite refractory lining (Clancy and Benson 1982). Secondary refining processes for steel making in the U.S. have limited experience with doloma (calcined dolomite) or magnesia-based refractories (Schroth 1983), even though dolomite has performed well in argon-oxygen-decarbonization furnaces, electric arc furnaces, continuous casting ladles, and rotary kilns for cement and lime, and in refining smelters for copper and nickel (Marr 1980).

The future of refractories in the U.S. may however be different. R.J. Marr (1980) of the J.E. Baker Company, shows that during the past decade substantial growth has taken place in the use of high-purity doloma in the U.S. The trend follows a need for strict chemistry control and the desire for lower costs in steel refining. Marr points out that high-purity dolomite (97% grade doloma) is more refractory than high-grade magnesia (87% grade magnesia) because it is denser and contains less melt liquids at high temperatures. This superior material requires 40% less energy to produce, and is cheaper than 87% grade magnesia in the U.S. It also has technical advantages over traditional North American refractories in certain processes, where it can substitute for magnesia, magnesia-chromite, and alumina refractories.

Energy considerations are a third reason that may make dolomite an economically attractive raw material, either for dolomite brick or as a starting point for magnesia refractory mixes. Between 1978 and 1980 the cost of energy in the U.S. more than doubled (Duncan and McCracken 1981), and between 1970 and 1980 crude oil increased in price 15-fold (Mills 1983). Predictions by these authors and others (Prentice 1983) show that whatever the selling price of crude oil, the cost of winning it will continue to rise, thereby preventing a net decrease of the price. Energy efficiency is thus a vital component of industrial viability, which has dramatic impact in an energy-intensive business such as refractories production.

The large amounts of heat energy required can be illustrated in the production of magnesia refractories. Much of the world's high-purity magnesia is produced by a 2-stage process in which calcined dolomite or limestone is reacted with seawater to precipitate insoluble magnesium hydroxide, which is then further calcined to magnesium oxide. The typical energy required for such 2-stage production is about 20 million British Thermal Units per ton of product (Duncan and McCracken 1981).

Savings of energy can be made at both stages of calcining by using vertical shaft kilns, or by selecting dolomite rather than limestone as the reagent (Williamson 1982). Greater savings result from using doloma as the lining rather than magnesia because doloma requires only 60% as much energy to produce (Marr 1980). Dolomites which naturally calcine to a dense grain in a single firing represent another considerable energy saving.

Many different materials and processes may be chosen to provide the high performance refractories needed by individual industries. The choices may be different if energy saving or materials substitution are the prime requirement. In each case, these choices depend upon carefully documented knowledge of the raw materials available, and upon technology ready to accept them.

With thinking such as this in mind the United States Bureau of Mines (USBM) has already begun research to widen the uses of dolomite, and proposes studies which will increase the quantity of dolomite resources suitable for high-density refractory grains (Clancy and Benson 1982).

Advantages to Ontario

Dolomites of top quality are not common worldwide. Marr (1980) points out that only 10 producers (6 major suppliers) can fulfill the requirements of uniformity, purity, and calcining behaviour needed in dolomites of refractory grade. The number and location of these producers is determined by the presence of suitable raw materials. Ontario is, at present, the sole supplier of metallurgical dolomite with ready access to cheap transport on the Great Lakes.

Dolomite consumption worldwide is closely tied to the fortunes of the steel industry. Since the 1970s, this industry has been depressed and real production in the 1980s fell well below predictions (Smith 1983), although some signs of recovery can now be seen. In western Europe, at the end of 1982 only 55% of production capacity was in use; it was 60% by mid-July 1983. Production in the U.S. had risen from 32.7 to 56% in the same period. Markets for magnesium metal are again rising after a dramatic fall in 1974. Another rising market is in the glass industry where process changes developed in the United Kingdom show that the batch price of glass can be reduced by adding dolomite to the melt (Smith 1983).

If rationalization in steel making, process changes in the glass industry, and rising magnesium markets all point to increased dolomite usage, Ontario may be in a good position to sell more high-magnesia raw materials, if they can be found. The combination of high-quality natural supplies which are well placed geographically, and energy at reasonable cost, may make market opportunities for basic refractory materials which were not available before.

Recent Raw Materials Research

Concern over the dependence of the U.S. on imported chromium is discussed by Papp (1983), and the arguments above underlie an interest in refractory-grade dolomites shown by the USBM.

Characteristics of the Refractory Raw Material

Chemical purity is important for raw dolomite of refractory grade; values of iron, alumina, silica, and boron must be particularly low. Weitz (1942) defines high-grade dolomite materials as those with 98% total carbonates and less than 2% impurities including iron oxides, alumina, and silica.

In the production of refractory material, dolomite ($(Ca,Mg)CO_3$) is calcined, precipitated as magnesium hydroxide ($Mg(OH)_2$), and then further calcined to periclase (MgO). The common impurities SiO_2, Fe_2O_3 and Al_2O_3 may form insoluble compounds which contaminate the precipated hydroxide. About 0.1% of impurity in the raw dolomite produces about 0.25% impurity in the corresponding periclase (Williamson 1982).

Purity is also related to the density obtained on calcining; dense calcined material has little volume change on further heating. This gives a tough, thermally-stable furnace lining which is highly desirable.

Conversely, the presence of alumina (Clancy and Benson 1982) or boron permits the formation of low-temperature liquid phases which cause creep and slumping in the lining materials. Mass fractions of as little as 0.1 to 0.3% B_2O_3 in seawater magnesia, for example, reduce the temperature of melt formation to 1000° to 1100°C (Williamson 1982). The loss of hot strength is obviously serious when the working temperature of many furnaces is much over 2000°C.

The density and functional properties of the periclase (MgO) finally produced depend upon its grain size and crystallinity. These in turn are affected by the crystallography of precursor minerals (in this case $Mg(OH)_2$ or $MgCO_3$), the chemical influences of trace impurities, and the temperature of calcining. Ideally a dolomite should calcine to a dense granular product of over 3.0 gm/cc in a single firing step. Texturally it should be relatively nonporous, and should resist spontaneous hydration in air (Clancy and Benson 1982).

Specifications in Practical Use

The theoretical molecular ratio for dolomite corresponds to 30.4% CaO, 21.7% MgO, and 47.9% CO_2.

The composition and properties of some refractory grade dolomites are shown in Table 1, compiled from Chesters (1973), Windes (1949,1950), and Blair (1955). Other industries have comparable specifications.

For metallurgical fluxing dolomite should contain less than 3% impurities (Hewitt 1960) and, because the flux is used to control the sulphur and phosphorus content of the steel, the raw material itself must have a low content of these elements. For the glass industry, greater than 96% CaO + MgO, less than 0.1% iron, and less than 4% combined $SiO_2 + Al_2O_3$ is required (Hewitt 1960). Dolomite used for magnesium metal production in Japan (Smith 1983) assays 65.1% CaO, 33% MgO, 0.5% SiO_2, 0.3% Al_2O_3, and 0.1% Fe_2O_3. Other assays for this use are given by Pidgeon (1944). Specifications in use by the steel industry in 1960, and earlier by the glass industries, are quoted in Table 2.

Recent specifications for the iron and steel industries (Smith 1983) from other parts of the world are given in Table 3.

As feedstuff for the ceramics industries, raw dolomite must contain a minimum of 30% CaO, and 21.4% MgO. The highest permissible levels of other oxides are 0.2%, of which Fe_2O_3 must not exceed 0.03%. Hygroscopic water in the milled products must not exceed 5%. For glazes and ceramics, dolomite flour has an upper grain size limit of 0.63 mm (Konta 1982).

Key Criteria for Evaluation of Dolomite

Chemical purity, the resistance of the calcined material to hydration, and the specific gravity were characteristics which Clancy and Benson (1982) found to indicate dolomite of high quality. They found tentative correlations with crystallographic textures which may give additional field criteria for identification.

The 14 samples examined by Clancy and Benson (1982) showed less than 2 weight percent impurities, and total

TABLE 1 PROPERTIES OF RAW REFRACTORY GRADE DOLOMITES (from Chesters 1973; Windes 1949, 1950; Blair 1955)

UNITED STATES

MgO	Chemical analysis, weight percent CaO	SiO_2	Al_2O_3	Fe_2O_3	LOI*	Apparent specific gravity	Accessory mineral phases**	Hydration wt%	Calculated liquid phase wt%	Bulk density g/ml	Porosity %
20.80	30.19	1.12	.56	.22	46.68	2.87	Q,C	83.5	10.4		
20.39	30.13	1.11	.39	.31	47.30	2.86	Q	80.9	9.8		
20.12	30.52	1.48	.82	.27	46.47	2.85	Q,C	48.4	15.2		
21.20	30.61	.02	.11	.06	47.54	2.87	Q	100.0	0.5		
19.46	29.57	1.69	.83	2.99	45.05	2.84	Q	—	—		
20.99	30.13	.40	.68	.12	47.26	2.87	Q	00.0	8.9		
21.26	27.61	.16	.06	.30	46.41	2.85	Q	72.6	2.3		
21.01	30.76	.29	.22	.39	47.08	2.86	Q,C	95.1	4.2		
21.22	30.83	.15	.20	.22	47.06	2.81	C	58.3	2.3		
21.18	30.61	.49	.08	.10	47.19	2.84	Q,C	98.6	4.6		
20.95	30.34	.52	.08	.19	47.42	2.84	Q,C	—	—		
19.20	31.16	.31	.12	3.61	45.44	2.84	Q,C	5.4	13.8		
21.16	30.78	.27	.04	.18	46.95	2.86	Q,C	99.5	2.3		
21.70	31.07	.50	.07	.15	45.85	2.82	Q,C	98.8	4.2		

BRITISH ISLES

MgO	Chemical analysis, weight percent CaO	SiO_2	$Al_2O_3 + Fe_2O_3$	LOI*	Apparent specific gravity	Accessory mineral phases	Hydration wt%	Calculated liquid phase	Bulk density g/ml	Porosity %
21.0	30.1	.40	.80	47.20	2.87				2.66	7.9
21.2	30.6	.02	.17	47.50	2.87				2.55	2.51
21.1	30.8	.30	.65	47.10	2.84				2.78	2.1
19.2	31.16	.31	3.73	45.44	2.84				2.68	6.0
21.50	30.63	0.33	0.52	47.37	2.84				2.47	5.11
21.28	30.25	0.74	.72	47.00	2.84				2.41	3.01
21.23	30.32	.87	.60	47.13	2.85				2.39	6.31
20.6	30.6	.89	.96	46.95	2.85				2.53	1.21
19.41	32.48	1.28	.81	45.15	2.82				2.77	1.8

PURE DOLOMITE

MgO	CaO	SiO_2	$Al_2O_3 + Fe_2O_3$	LOI*	Apparent specific gravity	Accessory mineral phases	Hydration wt%	Calculated liquid phase	Bulk density g/ml	Porosity %
21.87	30.41	—	—	47.72	2.87				—	—

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*LOI: Loss on Ignition
**Q: quartz, C: calcite

combined weight percent for MgO and CaO was at least 49% in the raw material. Values for loss-on-ignition (LOI) were 45 to 47 weight percent. Impurities also influence the reactivity of calcined material. Clancy and Benson (1982) found that there is a broad correlation between resistance to hydration and the amounts of liquid phase calculated to form on firing at 1550°C. Samples with more liquid phase are less susceptible to hydration. In other words, the less pure calcine is easier to handle because it does not hydrate as readily in air, but it is a less refractory material because the impurities contribute to low temperature melt phases.

These authors conclude that an apparent specific gravity of greater than 2.80 indicates a dolomite which will calcine to the required high density of more than 3.0 gm/cc. Only 2 of their samples calcined to high density in a single firing. Both were Lower Cambrian dolomite from Pennsylvania in which recrystallization had removed all trace of origin and produced large, twinned crystals. The authors are investigating further the relationship of microscopic texture to the density acquired on firing, which may help field recognition of quality dolomite.

Ontario Dolomite Resources of Precambrian Age

Deposits of high-purity dolomite in the Precambrian rocks north of Belleville and Kingston were documented as early as 1863. Recent mapping in Belmont, Madoc, and Marmora Townships (Bourque 1982; M.S. Bourque, Geologist, Ontario Geological Survey, Toronto, personal communication, 1983) together with new chemical data (Papertzian and Kingston 1982a, 1982b) offer a starting point for further evaluation.

The geographical position of these deposits is favourable. In Madoc Township, thick dolomite horizons lie less than 15 km from Provincial Highway 7, a major east-west transport route. Lake Ontario is about 60 km due south. A heavy concentration of important potential users, the iron and steel industries, glass manufacturers, agricultural dolime producers, and refractories manufacturers, are located in southwestern Ontario and across the border in the northern U.S.

TABLE 2 **COMPOSITIONS OF METALLURGICAL FLUX AND FLINT GLASS**

METALLURGICAL FLUX Ontario 1960 (Hewitt 1960)	%	FLINT GLASS Ontario 1904 (Miller 1904)	%
CaCO$_3$ MgCO$_3$	97	CaCO	55.60
		MgO	41.43
SiO$_2$	0.5	SiO$_2$	1.00
Al$_2$O$_3$	1.0	Al$_2$O$_3$	0.40
S	0.1	Fe$_2$O$_3$	0.12
		Organic	0.05
		Hygroscopic	0.40

In Ontario, at present, supplies of metallurgical-grade dolomite come from Manitoulin Island (Smith 1983) and the mainland outcrop (Scott and Yundt 1983). The source rocks are unmetamorphosed Middle to Lower Silurian dolomite. Flux and refractory dolomite comes from rocks of this age in southwestern Ontario (Hewitt 1960; Scott and Yundt 1983). Recent analytical data from Manitoulin Island (Johnson and Telford 1981; Johnson 1983) show low values for sulphur and phosphorus, but an average of 500 parts per million fluorine.

For Precambrian dolomite, in addition to the exceptional purity (Table 4), there are good indications that, by analogy with the high-quality dolomite of the U.S., these materials may require lower calcining energies than younger rocks. In Clancy and Benson's (1982) study, the only dolomites that fired to high density in a single calcine were thoroughly metamorphosed rocks of Lower Cambrian age. These authors also suggest that a specific gravity of greater than 2.80 indicates a potentially high density for the calcined product. Early records from the Grenville (Geological Survey of Canada 1863, p.592-593) quote specific gravities of 2.849 and 2.834 for dolomite from Madoc Township (Table 4).

Present Work

The discussion above outlines the criteria which distinguishes good-quality dolomite. Using existing maps and analyses, an examination of dolomite horizons in Madoc Township has begun, to see whether pure Precambrian dolomite, in bodies large enough to be economic, can be found close to transportation routes. Other factors such as cover rock thickness, fracturing, and secondary mineralization, all of which influence mining practice, have also been considered. The search has been directed towards dolomite of purity suitable for refractory or metallurgical processes. Whole rock analyses of the specimens collected this summer will also determine sulphur and boron content. These troublesome elements have not been documented in earlier Precambrian analyses.

Map Information

Madoc Township lies about 190 km northeast of Toronto. The geology is shown at 1:31 680 on Ontario Geological Survey Map 2154 (Hewitt 1968). Earlier mapping at 1:12 000 (Miller and Knight 1914) distinguished calcitic and magnesian limestone in parts of Madoc and Huntingdon Townships to the south. NTS map sheets 31 C/5,6,11,12 (Campbellford, Tweed, Kaladar, and Bannockburn), cover the area at 1:50 000. Recent geological mapping, with particular emphasis on carbonate stratigraphy, has been carried out by the Ontario Geological Survey (Bourque 1981, 1982). The maps and final manuscripts are in preparation. Limestone resources and much other information are given by Miller (1904). The report of the Royal Commission of 1890, Hewitt (1960, 1964), and Hewitt and Vos (1972) discuss the limestone industries in several publications.

Table 4 lists the chemical data and specific gravity measurements from reference sources. Figure 1 shows the locations of the measurements. Descriptions of locations for the information collected in 1863 do not allow more than rough geographical location by lot and concession.

Calibration of Analytical Data in Open File Report 5378

The analyses presented in this Open File Report (Papertzian and Kingston 1982a) must be used with care. The compositional range of many samples submitted has inadvertently made the analytical methods applied inappropriate (Chris Riddle, Chief Analyst, Geoscience Laboratories, Ontario Geological Survey, Toronto, personal communication, 1983). This contributes to total oxide values with limits of error of ± 10%. For pure dolomite, where a precision of ± 5% total R$_2$O$_3$ is required, this is not acceptable.

To correct for this, the database has been carefully re-examined and recalculated. It has been assumed (after consultation with Chris Riddle and A. Vander Voet, Analysts, Ontario Geoscience Laboratories) that methods for analysing SiO$_2$ at less than 5%, and Al$_2$O$_3$ and Fe$_2$O$_3$ at less than 2%, are not subject to significant error. Compar-

TABLE 3 **COMPOSITIONS OF DOLOMITE FLUX USED 1983**

CaCO$_3$	MgO	SiO$_2$	Fe$_2$O$_3$	Al$_2$O$_3$	MnO	S	
30	20	2	0.75	0.31	0.69		Verwoerdburg S. Africa
64.6	32	0.6	0.6	0.2			Aisawa, Japan
29	19.79	2-3.89					Machkot, India

TABLE 4 CHEMICAL AND SPECIFIC GRAVITY DATA FOR DOLOMITES, MADOC TOWNSHIP (refer to Figure 1)

	GSC (1863)		Miller and Knight (1914)							Papertzian and Kingston (1982a)			
Number	1	2	3	4	5	6	7	8	9	10	11	12	13
CaO	26.04	32.14	30.36	31.12	26.30	30.42	28.15	29.94	29.39	29.28	28.66	29.62	29.96
MgO	19.21	16.57	20.20	20.11	18.40	20.25	19.00	21.07	20.06	20.39	20.09	20.89	21.03
SiO_2	—	—	—	—	—	—	—	—	—	1.40	3.80	0.88	0.00
Fe_2O_3	1.24	1.32	3.70	1.60	1.28	1.70	1.66	—	—	0.43	0.37	0.16	0.10
Al_2O_3	—	—	—	—	—	—	—	—	—	0.68	0.44	0.27	0.18
CO_2	41.40	43.32	44.34	45.79	—	44.62	42.54	46.02	44.80	44.80	43.70	45.10	46.60
Insoluble	12.16	7.10	1.00	1.13	13.30	2.60	8.36	1.28	3.18	—	—	—	—
				—	—	—	—	—	—	—	—	—	—
			99.60	99.75	—	99.59	—	—	—	—	—	—	—
Specific Gravity	2.849	2.834					2.757						

ison of the LOI was then made against the total CO_2 required by the CaO + MgO present. Where the LOI agrees with the calculated value within 3%, the analysis is assumed to be correct within normal limits of error. This method has permitted calibration of the original data.

Field Mapping

On the basis of former records a small portion of Madoc Township was chosen for detailed examination. Figure 2 shows a block centred around Highway 62 which stretches north-south from Eldorado to Keller Bridge. It occupies parts of lots 16 to 25 of concessions V and VI, which are shown on Map 2154 (Hewitt 1968).

The simplified sketch shows only the dolomite horizons. Stratigraphic outlines are taken from M.S. Bourque (Geologist, Ontario Geological Survey, personal communication, 1983) and Hewitt (1968). Outliers of Paleozoic rocks and the lithology of other Precambrian rocks have been omitted, but may be found on maps by Hewitt (1968) and Carson (1980, 1981).

Field Appearance

The dolomite horizons are commonly composed of fine buff or yellow carbonate, with an even grain size. Intercalations of argillaceous or other carbonate rocks are seen near the margins of the main dolomite unit (D2, D3, D17, Figure 2). Here the dolomite is laminated and resembles a lithographic limestone in texture. In the centre of the unit the dolomite is commonly massive with a waxy or cherty appearance (D6, D9 to 11, D7 to 8) and a semi-conchoidal fracture. Near the former Eldorado Talc Mine, however, the original rocks seem to have been less pure. Here about 20% of calc-silicate minerals are developed and the rock is coarsely recrystallized.

Silica Bodies

Secondary quartz which fills fault planes or tension gashes is a minor constituent of many of the carbonate horizons. This type of quartz could be selectively removed in mining with little difficulty (e.g. D4 to 6, D9 to 11).

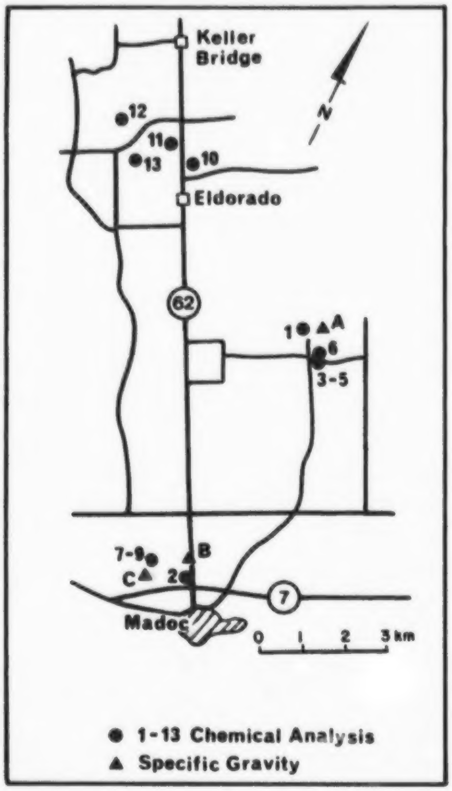

Figure 1. Sample sites for chemical and specific gravity data shown in Table 4.

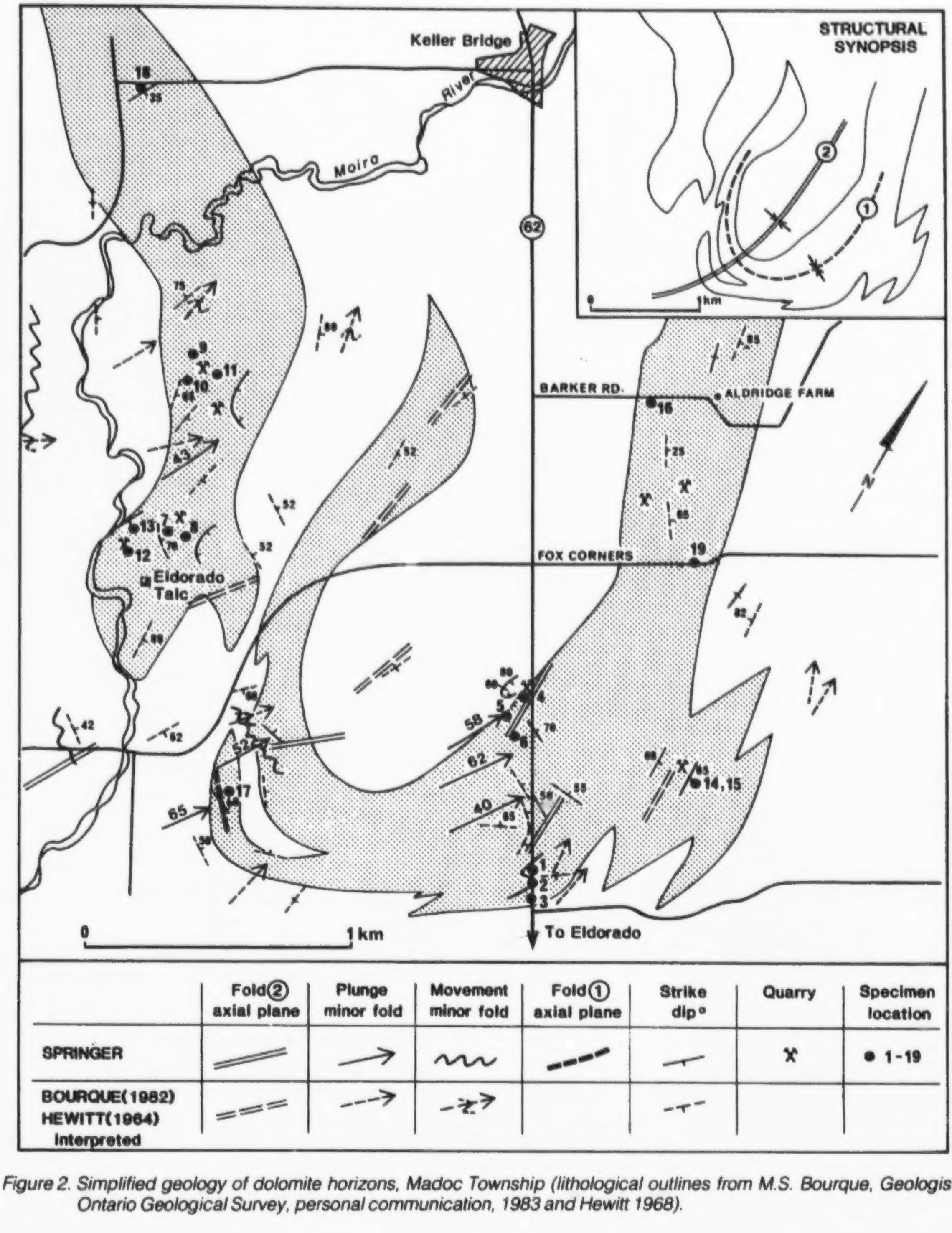
Keller Bridge
Moira
River
62
STRUCTURAL SYNOPSIS
2
1
0
1km
BARKER RD.
ALDRIDGE FARM
FOX CORNERS
Eldorado Talc
N
0
1 km
To Eldorado
18
9
10
11
13
7
8
12
16
19
4
5
6
14,15
17
1
2
3
58
62
40
65
52
Fold ② axial plane
Plunge minor fold
Movement minor fold
Fold ① axial plane
Strike dip °
Quarry
Specimen location
SPRINGER
1-19
BOURQUE(1982)
HEWITT(1964)
Interpreted

Figure 2. Simplified geology of dolomite horizons, Madoc Township (lithological outlines from M.S. Bourque, Geologist, Ontario Geological Survey, personal communication, 1983 and Hewitt 1968).

An earlier generation of quartz segregations has been described by Bourque (1982) and Bourque *et al.* (1983) as organo-sedimentary structures. They are interpreted to be relict patches of algal stromatolites which have been silicified and recrystallized. In the field, these are sheetlike bodies of very white, milky quartz; some of the largest, observed west of the Aldridge Property on Barker Road, reach 15 to 20 m in length, and are 10 to 20 cm thick. Commonly, the quartz shows millimetre-thick laminations as an internal structure parallel to the strike extension, and occasionally a match-like rodding of mineral grains normal to this banding.

Quartz of this type would present considerable difficulty in grade control. No dolomite samples were collected from the Aldridge locality or from the Eldorado Talc Mine, because the lamellar quartz horizons are too closely spaced to permit mining. Careful selection would also be needed at localities D11, D14 to 15, and D19.

Major Fold Structures

A large synformal fold (Figure 2 and inset) plunges on average 60°NE. It is a roughly isoclinal structure whose westerly limb dips 70° to 80° east; the easterly limb is vertical or dips steeply east. The nose of the structure strikes 115° with a dip of 60°NE. At specimen locality 17 (Figure 2), where thinly-banded calcite marble is intercalated with more massive dolomite horizons, and at localities D1, D2, and D3 on Highway 62, it is evident that earlier folds pre-date this major synform. The sense of movement on the earlier structures is consistent with a fold structure closing southwest, which is refolded across the synformal axial trace (Figure 2, inset). The patterns of minor folds, the limb attitudes, and the development of cleavages or fabrics parallel to axial planar structures, all require careful mapping before the continuity and quality of the dolomite beds can be assessed.

Faulting

Faulting is evident at localities D12 and D13; quartz-filled gashes which also show fault displacements can be seen in many places. The form of the Moira River seems partly fault controlled.

Earlier mapping gives little indication of displacement to the Precambrian and later rocks, although there is an evident influence of fault topography on the outlier of Paleozoic rock which runs between Fox Corners and Keller Bridge (Map 2154, Hewitt 1968).

The Pre-Paleozoic Land Surface

Block faulting, combined with variable resistance to weathering, gave rise to a hilly pre-Paleozoic terrain. Field relationships show that at the beginning of the Paleozoic the dolomite formed ridges pocked with the grikes and solution hollows of a karst landscape. Reddish basal Paleozoic sediments were deposited on this surface. Gritty, red sandstone and shale fill the grikes and stain the rocks below for 20 to 30 cm (localities D1 to 3, D4 to 6, D16). Later, this knobby surface influenced glacial scouring. Some parts have retained a Paleozoic cover, but the high relief of the tougher dolomite has ensured that the rocks above it have commonly been stripped back to this old land surface.

Because the form and position of the basal Paleozoic unconformity are features directly related to the viability of the dolomite horizons, they must be carefully mapped.

Specimens for Chemical Analysis

Samples collected for chemical analysis were first screened for other criteria of economic viability.

The desired orebody would be required to have: less than 5 m overburden; visibly low amounts of primary quartz or secondary quartz-veining; visibly low amounts of iron minerals in fracture planes or as iron-staining within the body of the rock; little intercalation of calcitic limestones; and cross-strike thicknesses of at least 3 m, in order to permit easy working with machinery at least as large as a backhoe.

The sample localities shown on Figure 2 are therefore a short list which estimates quality and viability.

Conclusions

Large thicknesses of good quality dolomite are exposed in a northeast-plunging synformal structure near Fox Corners on Highway 62. The strike section north along the eastern bank of the Moira River seems particularly pure. Several newer quarries are being sporadically worked here for aggregate.

Mapping is required to establish how folding has repeated the lithological units and whether the dolomite quality varies with its structural position in the folds. The structural elements of these folds, and the patterns of fracture and displacement will influence the mining characteristics of this unit.

Most of the good dolomite localities have less than 2 m overburden. Iron-staining from pre-Paleozoic weathering and from the basal Paleozoic deposits has seeped about 0.5 m down from the surface; ferruginous secondary minerals locally extend 1 to 2 m from the surface down fracture planes. Below this the dolomite is clean. Contamination by quartz is easily visible and could be avoided by selection at many localities.

Although more chemical analyses are needed to test the purity of this dolomite, especially for the particularly troublesome elements boron and sulphur, it appears, from analyses and specific gravity values obtained by previous workers, that these are high-purity dolostones. The specific gravities suggest, by analogy with densities achieved in the U.S. from calcined dolomites, that these rocks will produce a dense doloma grain.

The Fox Corners area already has several existing quarries of quality material less than 2 km from Highway 62. It seems well suited as a potential supplier of special purity dolomite for metallurgical use. It may be the kind of dolomite that will calcine to the high density grain much valued by the refractories industry.

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